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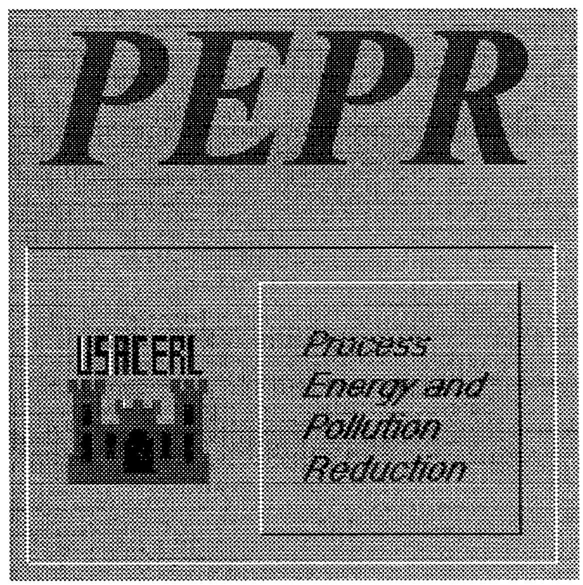
Review of Department of Defense Industrial Processes and Process Energy

by
Mike C.J. Lin, Malcolm Fraser, and Robert Lorand



Defense Energy Program Memorandum (DEPPM) 91-2 and Executive Order 12759 assign energy efficiency goals for Federal facilities for Fiscal Year 2000 (FY00) as compared to base year FY85. Each Department of Defense (DOD) component is directed to prescribe policies and establish appropriate measures to improve energy efficiency of the aggregate of its industrial energy-consuming facilities by at least 20 percent in FY00 in comparison to FY85. In most instances, these new energy and environmental directives exceed the performance capabilities of DOD's installed industrial technologies. (The vast majority of DOD industrial activities use technologies that are over 40 years old.) Cost-effective compliance with these directives in the existing DOD industrial base requires a thorough evaluation of DOD industrial activities and their potential for improvements.

This project began that evaluation and identified a wide range of low-cost energy and pollution reduction opportunities and energy conservation opportunities (ECOs) at DOD industrial facilities in which reduced energy consumption can, via energy efficiency and operational improvements, simultaneously and significantly reduce pollutant emissions at DOD industrial facilities within the Departments of the Army, Navy, and Air Force.

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13. ABSTRACT (Maximum 200 words)

Defense Energy Program Memorandum (DEPPM) 91-2 and Executive Order 12759 assign energy efficiency goals for Federal facilities for Fiscal Year 2000 (FY00) as compared to base year FY85. Each Department of Defense (DOD) component is directed to prescribe policies and establish appropriate measures to improve energy efficiency of the aggregate of its industrial energy-consuming facilities by at least 20 percent in FY00 in comparison to FY85. In most instances, these new energy and environmental directives exceed the performance capabilities of DOD's installed industrial technologies. (The vast majority of DOD industrial activities use technologies that are over 40 years old.) Cost-effective compliance with these directives in the existing DOD industrial base requires a thorough evaluation of DOD industrial activities and their potential for improvements.

This project began that evaluation and identified a wide range of low-cost energy and pollution reduction opportunities and energy conservation opportunities (ECOs) at DOD industrial facilities in which reduced energy consumption can, via energy efficiency and operational improvements, simultaneously and significantly reduce pollutant emissions at DOD industrial facilities within the Departments of the Army, Navy, and Air Force.

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Foreword

This study was conducted for the Office of the Assistant Secretary of Defense for Economic Security under Funding Acquisition Document (FAD) No. 95-08003; "Energy and Pollution Reduction Opportunity Identification for DOD Facilities." The technical monitor was Millard Carr, ODUSD/ES/C&I.

The work was performed by the Industrial Operations Division (UL-I) of the Utilities and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Dr. Mike C.J. Lin. Ralph E. Moshage is Acting Chief, CECER-UL-I and John T. Bandy is Operations Chief, CECER-UL. The USACERL technical editor was William J. Wolfe, Technical Resources Center.

COL James T. Scott is Commander of USACERL, and Dr. Michael J. O'Connor is Director.

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1 Introduction

1.1 Background

Defense Energy Program Memorandum (DEPPM) 91-2 and Executive Order 12759 assign energy efficiency goals for Federal facilities for Fiscal Year 2000 (FY00) as compared to base year FY85. Specifically, each Department of Defense (DOD) component is directed to prescribe policies and establish appropriate measures to improve energy efficiency of the aggregate of its industrial energy-consuming facilities by at least 20 percent in FY00 in comparison to FY85. Executive Order 12902 calls for an increased energy efficiency in Federal industrial facilities by at least 20 percent by 2005 compared to FY90 and requires agencies to implement all cost-effective water conservation projects. This Order also increases the energy savings requirement for agencies to 30 percent by 2005 compared to FY85 in Btu per gross square foot.

Executive Order 12856 requires the Army to reduce energy use and its related environmental impacts by promoting renewable energy technologies. Section 3-302(a) requires a 50-percent reduction in toxic chemical and pollutant releases to the environment by 31 December 1999. Executive Order 12873 requires the Army to incorporate waste prevention and recycling in everyday operations, and to acquire and use "environmentally preferable" products and services to the maximum extent practicable. Since 1 April 1994, Section 503 has required periodic modification to procurement guidelines to incorporate the latest USEPA guidance.

In most instances, these new energy and environmental directives exceed the performance capabilities of DOD's installed industrial technologies. The vast majority of DOD industrial activities use technologies over 40 years old. Future DOD industrial facilities will employ state-of-the-art production technologies being developed jointly by the Army's ManTech program and the Department of Energy's (DOE's) Sandia National Laboratory.

Cost-effective compliance with these directives in the existing DOD industrial base will require a thorough evaluation of DOD industrial activities and their potential for improvements. Understanding energy-use patterns and options in DOD produc-

tion sites promises to be an invaluable aid in identifying energy and emission reduction opportunities.

1.2 Objectives

The objective of this project was to identify energy and pollution reduction opportunities at DOD industrial facilities in which reduced energy consumption can, via energy efficiency and operational improvements, simultaneously bring about significant reduction of pollutant emissions. Such opportunities were sought at DOD industrial facilities within the Departments of the Army, Navy, and Air Force. By addressing the potential linkage between energy consumption and environmental impacts, it was hoped to achieve the required energy and emissions goals in a more flexible, cost-effective manner than could be achieved through unrelated DOD efforts.

1.3 Approach

This project involved several tasks:

1. Major DOD industrial energy-consuming activities were screened and qualitatively evaluated with respect to their potential to emit pollutants, using the Institute for Defense Analysis (IDA) report as a base. Site visits were made to representative bases, one for each of the three services, to (a) collect and evaluate available energy consumption/emissions data, (b) directly observe various types of process activities and operations, and (c) examine facility conditions. Data were used to project potential industrial energy savings.

2. The DOD industrial processes and unit operations studied in the first task were evaluated to identify opportunities for energy/environmental projects with high savings to investment ratios (SIRs). Improvements were investigated based on five categories: (a) fuel/energy substitution, (b) process design modifications, (c) operational modifications, (d) control technology additions, or (e) technology replacement. Analysis results permitted a ranking of technical approaches according to both energy savings and emissions reduction, and provided inputs for cost-benefit analyses. A recommended list of potential projects was generated for implementation.

3. Project documentation was prepared highlighting the low-investment and high-payback project areas and DOD investments needed to reduce industrial energy consumption.

1.4 Scope

The collection of process data was limited to three site visits—to a representative base having significant industrial process activities for each of the three services, Army, Air Force, and Navy. Each site visit was limited to 4 or 5 days. The collection of data and descriptive information on the processes of interest that were surveyed at each base was limited to data immediately available either from base personnel or observation. No measurements were made. The energy conservation opportunities (ECOs) that were identified are limited to the processes surveyed. The projections of potential energy savings at all similar DOD bases were made from the data for the surveyed processes.

1.5 Mode of Technology Transfer

It is anticipated that the information presented in this report will be published in the Army Research, Development and Acquisition Bulletin, and that the energy/emission review results obtained and the software tool developed will be presented at the Annual Joint Service Pollution Prevention Conference.

The PEPR program may be obtained by contacting the USACERL Industrial Operations Division at (800) 872-2375, extension 3487. The program will be transferred to the Office of the Assistant Secretary of Defense for Economic Security for further distribution.

1.6 Metric Conversion Table

The following metric conversions are provided for standard units of measure used throughout this report:

1 ft	=	0.305 m
1 sq ft	=	0.093 m^2
1 sq in.	=	6.45 cm^2
1 cu ft	=	0.028 m^3
1 lb	=	0.453 kg
1 gal	=	3.78 L
1 oz.	=	29.57 mL
1 psi	=	6.89 kPa
°F	=	(°C × 1.8) +32
1 Btu	=	1.055 kJ

2 Review of DOD Industrial Processes and Process Energy

2.1 Data Sources

2.1.1 DOD Process Energy Database

Energy consumption and cost data are collected for the three major branches of the DOD via the Defense Energy Information System (DEIS) (Hanson 1994). DEIS is the information system with which the DOD monitors its supplies and consumption of energy. It is primarily used as an energy management tool, providing information about each fuel used within the DOD, including bulk petroleum products (DEIS-I and DEIS-II databases) and the inventory, consumption, and costs of purchased utility energy (only DEIS-II database). The DEIS system was initiated in 1985, and data have been collected each year since then. Studies of energy consumption and opportunities for energy conservation within the DOD usually start with the data in this database.

One limitation of this database, however, is that there is no information describing in detail the use to which the energy is put or the type of equipment that uses the energy. Of interest to this project, of course, is the amount of energy used in DOD industrial processes. Energy consumption for industrial processes is reported as a separate activity by each installation on a voluntary basis. Energy is reported as process energy when industrial processes significantly impact the energy consumption at an installation.

Industrial process energy is defined as the facility energy directly consumed in the manufacture, rehabilitation, or refurbishment, and the destruction of products such as tanks, aircraft, ships, munitions, propellants and/or their component parts, and energy consumed in the movement of materials in automated warehouses. It excludes energy used for personal comfort, general administration, facility security, and housekeeping requirements. DOD industrial processes are extremely varied; some processes are quite common and may be found at a number of installations while others may be exclusive to only one installation.

The process energy data collected in DEIS-II is useful in locating the users of process energy and in quantifying how much energy is used in total—with some significant limitations—but does not identify the industrial processes for which the energy is used. According to one installation-level survey (Hanson 1994), DOD-wide generalizations cannot be drawn on the type of equipment being used or the amount and the type of energy being used within a particular installation in any particular process. Past studies attempting to characterize DOD industrial processes by relying only on the available DEIS data have not been fully successful. The available energy databases do not contain the proper information to adequately describe the processes and industrial equipment used at all DOD installations. To acquire adequate information to characterize all process energy usage throughout the DOD, surveys of numerous individual installations are needed. A recent study of DOD utility energy (IDA, August 1994) notes that this current lack of proper data makes studies of DOD industrial energy usage extremely difficult.

However, in another recent study (IDA, August 1994), researchers at the Institute for Defense Analysis (IDA) attempted to define the potential for energy reduction in DOD industrial processes with energy conservation measures. The analysis began with the DEIS-II energy database, which, despite its flaws, appears to be the only source that includes information on all the military services' process activities and facilities.

According to the DEIS-II database, DOD installations within CONUS+Alaska consumed 0.27 quads of utility energy of all types in F91 at a cost of $2 billion. Approximately 14 percent of this energy consumption was for process energy. About 100 DOD installations reported using some sort of process energy.

As noted above, the uses of energy for process functions in DOD appear to be numerous and varied. The IDA study (IDA, August 1994) identified and analyzed the opportunities for energy conservation and reduction in DOD processes essentially by: (1) assuming that such opportunities would be analogous to those found in private-sector industries in terms of type, quantity, and cost, and (2) applying data generated from private-industry energy audits (Department of Energy Industrial Conservation Opportunity [DEICO] database) to DOD bases. In the present project, energy conservation opportunities (ECOs) have been identified by surveying and analyzing specific DOD processes at specific installations. In addition, potential ECOs have been identified by applying the Process Energy and Pollution Reduction (PEPR) methodology (SAIC, November 1995) rather than relying on the more traditional type of energy audit.

The following sections describe: (1) industrial processes carried out by each of the three services, and (2) the quantities of energy ascribed to process functions for the types of installations where most of DOD's process energy appears to be used.

2.1.2 DOD Industrial Processes

Certain types of data would help to evaluate and rank-order energy savings opportunities for DOD industrial processes in terms of their aggregated total energy impact in all DOD industrial facilities, for example, data on the total annual production, by specific product, of the various products produced via these processes at these facilities. It would also be helpful to know: (1) what products are produced at the various candidate facilities, (2) what processes are carried out at each DOD facility, and (3) how many production lines of the various types are in operation. However, this type of information was found to be largely unavailable.

A previous project (*Army Pollution Prevention, Environmental Technology Program* 1995) identified sources of information on Army processes, and collected, compiled, and evaluated data to select five energy-intensive processes to put into the PEPR software screening tool, and identify potential ECOs. The types of reports evaluated for process information and energy/emissions data included energy analysis reports, air emissions inventory reports, and hazardous waste minimization studies.

2.1.2.1 Energy Analysis Reports. A series of Energy Engineering Analysis Reports for various facilities were completed in the late 1970s and the early 1980s and are listed in the References at the end of this report. Most of the reports of this type are more than 10 years old and, with only a few exceptions, do not contain the detailed energy consumption data and equipment descriptions needed for a comprehensive analysis of DOD industrial processes.

The primary purpose of many of these energy analysis reports was to analyze total facility energy consumption by using regression analysis to determine the important variables and to develop an equation for predicting energy consumption as a function of production level. Since energy consumption at the level of individual processes or process steps is virtually never directly measured or monitored, it should not be surprising that such data do not exist, but rather must be estimated with the aid of equipment specifications and engineering analysis. However, these reports contained little descriptive information on equipment that might have allowed engineering estimations of energy consumption.

2.1.2.2 Air Emissions Inventory Reports. A series of reports are being prepared to develop air emissions inventories at Army industrial facilities. Reports that were

available included those for Lonestar AAP, Iowa AAP, Radford AAP, Milan AAP, and Holston AAP. These reports, also listed in the References at the end of this report, are concerned, however, only with emissions data. There is only a minimal amount of information specifically about production lines, and there are no data on process energy usage except for central boilers. These reports typically have some descriptive information regarding process unit operations that are air pollution sources, along with estimated emissions. Air emissions emanating from a pollution source are, for the most part, estimated from data on material usage and accepted emission factors. These emission factors and calculations can be applied to other bases.

2.1.2.3 Reports on Hazardous Waste Minimization Studies. Reports on a number of recent hazardous waste minimization (HAZMIN) studies performed for the Army Materiel Command/Army Production Base Modernization Activity at Picatinny Arsenal were also examined as sources of information and data on Army industrial processes. These reports, listed in the References at the end of this report, were available for Radford, Longhorn, Lonestar, and Louisiana AAPs; and the electroplating line at Corpus Christi Army Depot. These reports contain descriptions of the processes with emphasis on wastes. These reports also contain a number of suggestions for process improvements (e.g., for Radford, to use less volatile solvents in propellant formulations [to reduce VOC emissions], or to transition to solventless propellants), but they contain no energy data.

2.1.2.4 Report by Institute for Defense Analysis. In the IDA report (August 1994) described briefly above, the identification and analysis of potential process ECOs were carried out by using data from audits of private-sector facilities. The report authors made several site visits to representative DOD bases, but did not document any data or descriptive information about the processes they may have observed. In addition, they were not able to collect any useful process information on DOD processes from any previous studies.

In contrast, the approach in the present study was to identify potential process ECOs for specific DOD processes at representative DOD bases, and to extrapolate and aggregate potential energy savings from this DOD-specific database.

2.1.2.5 Site Visits. The most fruitful source of information on DOD industrial processes at DOD facilities is without a doubt site visits. One of the most important elements of this project was to visit a representative base from each of the three services where industrial processes are carried out. The processes surveyed on these site visits are described in detail in the next chapter of this report, which also contains the collected energy/emissions data.

2.2 Process Descriptions and Categorization

2.2.1 Process Types

Table 1 summarizes the information on products and processes gleaned from collected reports (SAIC November 1995). It should be noted that these reports in general contained very little quantitative data on energy consumption and emissions associated with these processes. The processes listed fall into four main categories: (1) maintenance types of processes (disassembling, refurbishing parts, depainting, painting, assembling, etc.), (2) explosives production, (3) metal processing (forging, machining, and making metal components, etc.), and (4) loading, assembling, and packing such products as munitions of various types (LAP lines).

Table 1. Data collected on products and processes.

Facility	Product	Process Operations
Corpus Christi Army Depot	Large diverse plating/metal finishing shop producing parts (engines, transmissions, rotors, airframe sections) for helicopter maintenance	Maintenance type of processes
Holston AAP	Chemical support: acetic acid concentration acetic anhydride–manufacture & refining nitric acid (AOP) nitric acid concentration ammonium nitrate Explosives: RDX (Research Development Explosive - $C_3H_6N_6O_6$) HMX (High Melting Explosive - $C_4H_8N_8O_8$)	Chemical production processes
Iowa AAP	M106 shells (other sizes as well)	LAP lines
Lake City AAP	5.56mm: casings bullets assembly (also 7.62mm, 20mm, and 50 cal.) Primers Tracers Lead styphnate	

Facility	Product	Process Operations
Lonestar AAP	Anti-tank mines Personnel mines Cluster bombs Large-caliber artillery shells Other primers fuzes detonators delays tracers grenades	Apparently similar to other LAP lines
Longhorn AAP	Pyrotechnic ammunition illuminators flares signals	Apparently similar to other LAP lines
Louisiana AAP	Metal parts 155mm projectile casings ogives bases M692/M731 ADAM projectiles Claymore mines M112 demolition blocks	Apparently similar to other LAP lines
Milan AAP	Class A (high explosives): 120mm mortars M831, M835, M829 cartridges Class B (propellants)	Apparently similar to other LAP lines
Pine Bluff Arsenal	Smoke grenades	LAP lines
Radford AAP (some process descriptions and emissions data available via report on Badger AAP)	Chemical support: nitric acid (AOP) acid concentration (NAC-SAC) oleum (SAR) Main processes: nitrocellulose (NC) TNT nitroglycerin (NG) Propellants: single-base propellants (CASBL) multi-base propellants (CAMBL) rocket motors solventless propellants	Chemical production processes
Scranton AAP	Artillery casings (various sizes)	Metal processing

Facility	Product	Process Operations
Watervliet Arsenal	Mortars Cannon Components	Metal processing

The information on air pollution sources from the five air emissions inventory reports discussed above was examined to try to identify common types of process operations at these five bases. Table 2 lists the air emissions sources at the five bases described in these reports. The table has two parts: (a) Production Processes, which produce identifiable, readily quantified products, and (b) Generic Operations, which are not necessarily part of a process producing such products. With respect to production processes at these five bases, the table shows that there appears to be little commonality, except for load, assemble, and pack lines, and acid production. On the other hand, many generic operations are performed at all of these bases, but how much energy these operations consume remains in question.

2.2.2 Processes by Service

2.2.2.1 Army Processes. At the representative Army base selected for a site visit—Anniston Army Depot—the processes carried out to support the depot's mission of overhauling and repairing tanks and other heavy military vehicles, weapons, and missiles are:

- steam cleaning vehicles and parts
- disassembling vehicles
- electroplating vehicle components
- heat treating components
- abrasive blasting for removing old paint
- machining
- welding
- engine and transmission overhaul
- vehicle testing (dynamometers)
- sheet metal fabrication
- assembling vehicles
- spray painting vehicles and parts
- electronics repair.

Not all of these processes are energy-intensive, and not all of them were surveyed on the site visit. Those processes that were surveyed during the site visit are described in more detail in Chapter 3 of this report.

Table 2. Air emissions sources at Army industrial facilities.

a. Production Processes

Process	Holston	Iowa	Lonestar	Milan	Radford
Nitric and sulfuric acid production	· tail gas from nitric acid absorption column · unreacted NO_x from NAC				· spent-air compressors · sulfuric acid concentrators
Acetic acid and acetic anhydride	uncondensed reactants from distillation columns (vents)				
Explosives (RDX and HMX)	· condenser vent emissions from lacquer preparation · hexamine dust · VOCs from dissolving tank · VOCs and NO_x from wet scrubber vent · VOCs from dissolver-still condenser vent · PM_{10} from bed dryer scrubber · PM_{10} from TNT package system · PM_{10} from TNT kettle scrubber · PM_{10} from product packaging system · VOCs from acid recovery condenser vent				

Process	Holston	Iowa	Lonestar	Milan	Radford
Nitrocellulose					· drying · fume recovery molecular sieve system · nitrator · boiling tubs
Nitroglycerine					sealed system
Single- and multi-base propellants					· solvent emissions in every process step · solvent recovery system · finishing area · forced-air dryers
Rolled powder					· final mixer · pressing · cutting machines · cutting bays · traying · loading
Loading, assembling, and packing of ammunition and explosives		· mixing/blending · melting/pouring/drying · load/assemble/pack · PM_{10} and HAPs	· mixing/blending · melting/pouring/drying · load/assemble/pack · PM_{10} and HAPs	fugitive VOC emissions emanating from solvents used in wiping and cleaning	
Pyrotechnic mixtures—Mixer-Granulator-Dryer (MIGRAD) System			VOC emissions collected with a vacuum collection system		
b. Generic Operations					
Abrasive blasting	three machines	one machine			· sandblasting booths · portable units · grinding
Degreasing	cold	small recirculating diptanks	small diptanks	cold	cold and covered

Process	Holston	Iowa	Lonestar	Milan	Radford
Extrusion/spiral wrap					sawing and spiral wrap operations
Incinerators	two for burning refuse	· explosive waste · contaminated waste · deactivation furnace			· NO_x afterburner · waste propellant (2) · decontamination oven
Laundry		TSP from clothes dryers			
Machine shop				no emissions	
Painting	paint booth and misc.	spray booths	spray booths	spray booth	spray booths
Photoprocessing	· x-ray development · photofilm development			· x-ray development · photofilm development	
Printing		VOC emissions	VOC emissions		
Surface coating					curing and conditioning of teflon-coated items (heat used in ovens)
Waste solvent/oil recovery			batch distillation		
Water and wastewater treatment	· drinking water · sewage · industrial wastewater	primarily sewage treatment	· sewage · industrial wastewater	· drinking water · sewage · industrial wastewater	· drinking water · sewage · industrial wastewater
Welding	PM_{10} and HAP emissions	PM_{10} emissions, as needed basis	PM_{10} emissions	PM_{10} and HAP emissions	· 1/3 in shop · 2/3 in field
Woodworking	· cutting · sanding (no HAPs from pressure-treated wood)	· cutting · sanding (no HAPs from pressure-treated wood)	· cutting · sanding (no HAPs from pressure-treated wood)	· cutting · sanding (no HAPs from pressure-treated wood)	· cutting · sanding (no HAPs from pressure-treated wood)

2.2.2.2 Air Force Processes. The mission of the Air Logistics Centers is to provide systems and logistics support, and depot maintenance for weapons systems and aircraft fleets for the Air Force. The different centers are responsible for different weapons systems and types of aircraft.

At the representative Air Force base selected for a site visit—Robins Air Force Base—the processes that support the center's mission of overhauling and repairing (1) C-130s, C-141s, and F-15s and (2) avionics systems, weapons, and missiles are:

- cleaning aircraft and parts
- disassembling aircraft
- electroplating aircraft components
- heat treating components
- stripping and blasting for depainting aircraft
- machining
- welding
- engine overhaul
- sheet metal fabrication
- assembling aircraft
- spray painting aircraft and parts
- radome repair
- electronics repair.

A comparison of this list of processes with the list of Army processes in the previous section shows that similar types of industrial processes are carried out in the Army and the Air Force. However, it was found from the site visits that a number of these processes are quite different between the two services. Different materials and process conditions are involved in the Air Force processes. Radome repair is a process unique to the Air Force; however, this process involves the basic operations of depainting with solvents, sanding, heat-curing, painting, baking, etc. Again, not all of these Air Force processes are energy-intensive, and not all of them were surveyed on the site visit to Robins Air Logistics Center. Those processes which were surveyed during the site visit are described in more detail in Chapter 3 of this report.

2.2.2.3 Navy Processes. The primary function of Navy shipyards is to maintain surface ships and submarines. At the representative shipyard selected for a site visit—Norfolk Naval Shipyard—the processes carried out to support the yard's mission are:

- removing components from ships
- electroplating parts

- heat treating components
- stripping and blasting for depainting parts and components
- machining
- welding
- boilermaking (boiler overhaul)
- shipfitting (fabricating ship components)
- pipefitting
- sheet metal fabrication
- assembling ship components
- spray painting ships and parts
- motor rewinding
- electronics repair
- maintenance of diesel and nuclear power systems.

A number of these processes are similar to those found in the Army and the Air Force, although some processes are unique: boilermaking, shipfitting, motor rewinding, and overhauling nuclear power systems, for example. Not all of these processes are energy-intensive, and not all of them were surveyed on the site visit. Those processes surveyed during the site visit are described in more detail in Chapter 3 of this report.

2.3 Processes, Energy Consumption, and Pollution Generation

2.3.1 Army Processes

2.3.1.1 Bases and Energy Consumption. The primary operator of industrial facilities and, hence, user of process energy within the Army is the U.S. Army Materiel Command (AMC). AMC operates directly, or through contract, a number of large facilities across the United States These facilities fall into the following categories: Propellant and Explosive plants; Load, Assemble, and Pack plants; Small Arms Ammunition plants; Ammunition Metal plants; Manufacturing plants; Manufacturing Arsenals; Supply and Maintenance Depots; Supply Depots; Research and Development facilities; and Proving Grounds. They are either Government-owned Government-operated (GOGO), or Government-owned Contractor-operated (GOCO). Table 3 shows the total energy usage at AMC facilities by installation for fiscal year 1994 (FY94). This table shows the total amounts of energy consumed in: (1) gas, (2) oil, and (3) coal, (4) the total for these fuels (thermal energy), (5) electricity, (6) total energy (fuels plus electricity), and (7) the percent thermal energy. In terms of total energy, the top 10 bases are:

1. Radford AAP
2. Holston AAP
3. Aberdeen PG
4. Redstone Arsenal
5. Rock Island Arsenal
6. Picatinny Arsenal
7. Fort Monmouth
8. White Sands
9. Tobyhanna Army Depot
10. Lone Star AAP.

It is apparent that of the top 10 energy-consuming AMC installations, three are arsenals and three are ammunition plants. The processes at these types of facilities should therefore be emphasized in any study of process energy, potential energy conservation measures, and process improvements.

Of the total energy used at each of these AMC facilities, it is difficult to estimate that portion used strictly for process purposes as opposed to the energy used to operate the facility, such as energy used for heating buildings. Energy consumed in process equipment is generally not metered; nor is building energy consumption. The proportion of total energy reported for process use is only an estimate.

The recent IDA study (IDA, August 1994) attempted to define how much energy consumed at Army Ammunition Plants (AAP) could be considered process energy usage, using Holston AAP as a sample. The study concluded that probably 95 to 96 percent of total energy used was for process use, which included a large fixed amount for keeping the system energized and the plant open. However, Holston AAP may be an anomaly because it, like Radford AAP, is a Propellant and Explosive plant with chemical processes that are especially energy-intensive. This IDA study did not consider the energy used for process functions at other types of AMC bases, such as maintenance depots, other types of AAPs that operate LAP lines, etc.

2.3.1.2 Pollution Generation. Industrial processes at Army bases do emit a wide variety of pollutants. However, the most significant pollutants in terms of quantities appear to be VOC and HAP emissions from painting operations—as well as from the use of various solvents for cleaning—and hazardous wastes in the form of used blasting media. VOC and HAP emissions also result from the chemical production processes used to produce explosives, and various generic operations involving solvents. Emissions from plating processes are also a major concern.

Table 3. Energy usage in Army Materiel Command bases—FY94.

Base Name	Gas MBtu	Oil MBtu	Coal MBtu	Total Fuels	Electricity MBtu	Total MBtu	Percent Thermal
Aberdeen	16200	988402	0	1004602	800434	1805036	55.66
Anniston Dpt	29116	48093	253076	330285	211183	541468	61.00
Badger AAP	21961	0	0	21961	12533	34494	63.67
Corpus	4649	0	0	4649	186084	190733	2.44
Detroit ARS	380967	0	54642	435609	0	435609	100.00
Detroit	194692	15554	31329	241575	139363	380938	63.42
Dugway PG	0	119508	0	119508	107366	226874	52.68
Ft Monmouth	138649	520905	0	659554	300184	959738	68.72
Hawthorne	0	188914	2148499	188914	28099	217013	87.05
Holston AAP	1106	83		2149688	213459	2363147	90.97
Indiana AAP	0	75705	0	75706	47741	123447	61.33
Iowa AAP	112695	1229	430950	544874	66745	611619	89.09
Jefferson PG	0	48059	0	48059	14478	62537	76.85
Kansas AAP	0	164710	10200	174910	40096	215006	81.35
Lake City	466596	0	0	466596	143285	609881	76.51
Letterkenny	0	391858	0	391858	186766	578624	67.72
Lexington	7274	73239	85637	166150	59850	226000	73.52
Lima Tank	0	0	232795	232795	175039	407834	57.08
Lone Star	574041	411	0	574452	53362	627814	91.50
Longhorn AAP	424641	0	0	424641	73089	497730	85.32
Louisianna	156160	0	0	156160	120400	276560	56.47
Mcalester	173250	13520	0	186770	45502	232272	80.41
Milan AAP	0	66163	38417	104580	43174	147754	70.78
Mississippi	46870	0	0	46870	30540	77410	60.55
Natick Dev	30118	63667	0	93785	42567	136352	68.78
Newport AAP	147390	139950	0	287340	14761	302101	95.11
Picatinny	784266	62756	0	847022	204282	1051304	80.57
Pine Bluff	442994	0	0	442994	86045	529039	83.74
Pueblo Dpt	35209	15831	38794	89834	28714	118548	75.78
Radford AAP	0	23	2326874	2326897	328354	2655251	87.63
Ravenna AAP	0	14354	0	14354	6478	20832	68.90
Red River	89744	12920	279307	381971	201306	583277	65.49
Redstone Ars	314015	0	0	314015	1386354	1700369	18.47
Rock I. Ars	20097	7619	751858	779574	373840	1153414	67.59
Sacramento	136754	0	0	136754	62513	199267	68.63
Savanna	0	95395	8116	103511	16447	119958	86.29
Scranton AAP	106186	0	0	106186	95916	202102	52.54
Seneca Army	0	65340	0	65340	27048	92388	70.72
Sierra Army	7918	71708	0	79626	46048	125674	63.36
Sunflower	394806	13	0	394819	46772	441591	89.41

Base Name	Gas MBtu	Oil MBtu	Coal MBtu	Total Fuels	Electricity MBtu	Total MBtu	Percent Thermal
Tobyhanna AD	0	41980	527700	569680	138254	707934	80.47
Tooele Dpt	105796	259957	10363	376116	241432	617548	60.90
Twin Cities	207158	0	0	207158	122124	329282	62.91
Umatilla	0	29339	0	29339	10481	39820	73.68
Vint Hill	87229	0	0	87229	67581	154810	56.35
Volunteer	0	0	0	0	14823	14823	0.00
Watervliet	23812	311738	0	335550	157418	492968	68.07
White Sands	483805	0	0	483805	384113	867918	55.74
Yuma PG	4100	6072	0	10172	123086	133258	7.63

2.3.2 Air Force Processes

2.3.2.1 Bases and Energy Consumption. According to the analysis of process energy in the IDA report (IDA, August 1994), the use of process energy in Air Force facilities accounted for $94 million (M)—about 34 percent—of the $278M of reported expenditures in FY91 energy costs. This total process energy used by the Air Force was broken down in turn into process energy used by: (1) the five Air Logistics Centers ($75M in energy costs, or about one-quarter of DOD's total process energy), and (2) Arnold Engineering Development Center ($22M for this single base—almost 8 percent of DOD's process energy costs in 1991).

There currently are five Air Logistics Centers, located at: Hill Air Force Base, UT; Kelly Air Force Base, TX; McClellan Air Force Base, CA; Robins Air Force Base, GA; and Tinker Air Force Base, OK. Kelly and McClellan are slated to close by the year 2000. What will happen with their missions and related industrial process activities has not been determined. The primary role of these centers is to provide systems and logistics support for the Air Force. The Arnold Engineering Development Center at Arnold Air Force Station in Tullahoma, TN, is a national aerospace ground test facility serving both DOD customers (from all services) as well as commercial customers. Table 4 lists the amount of energy consumed at each of these installations.

2.3.2.2 Pollution Generation. The concerns about sources of pollution at Air Force bases are similar to those at Army bases. Large quantities of paint and a wide variety of solvents are used, resulting in significant VOC and HAP emissions from plating processes.

Table 4. Energy usage in Air Force Materiel Command bases—FY94.

Base Name	Gas MBtu	Oil MBtu	Coal MBtu	Total Fuels	Electricity MBtu	Total MBtu	Percent Thermal
Arnold	695993	8423	0	704416	2708407	3412823	20.64
Brooks	171800	501	0	172301	179718	352019	48.95
Edwards	580075	35416	0	615491	712116	1327607	46.36
Eglin	519533	0	0	519533	954838	1474371	35.24
Griffiss	104313	22828	620127	747268	289856	1037124	72.05
Hanscom	495250	234600	0	729850	370539	1100389	66.33
Hill	1236739	25158	0	1261897	838765	2100662	60.07
Kelly	916961	0	0	916961	1068617	1985578	46.18
Kirtland	773190	0	0	773190	392986	1166176	66.30
Los Angeles	77096	0	0	77096	121366	198462	38.85
Mcclellan	760353	0	0	760353	724925	1485278	51.19
Newark	100374	0	0	100374	162636	263013	38.16
Robins	1147770	24570	0	1172340	894018	2066358	56.73
Tinker	1347852	0	0	1347852	1149891	2497743	53.96
Wright-Patterson	350416	25042	1964825	2340283	1484402	3824685	61.19

2.3.3 Navy Processes

2.3.3.1 Bases and Energy Consumption. According to the analysis of process energy in the IDA report (IDA August 1994), the use of process energy in Navy facilities accounted for about half of the total process energy reported in the DEIS-II database. This total process energy used by the Navy was broken down in turn into process energy used by: (1) Navy shipyards and (2) other Navy industrial facilities, primarily reserve industrial plants. Process energy used at shipyards accounted for $70M (about 25 percent) of the $278M of reported expenditures in FY91 energy costs. The "other Navy facilities" accounted for a similar amount.

With respect to shipyards, the Navy currently operates eight shipyards, located at Charleston, SC; Long Beach, CA; Mare Island, CA; Pearl Harbor, HI; Philadelphia, PA; Portsmouth, NH; Portsmouth, VA; and Puget Sound, WA. Three are slated for closure—Philadelphia, Long Beach, and Charleston.

The amount of energy used at each one of these shipyards does not appear to be available in the REEP-PEPR database (SAIC November 1995) because some Navy energy data is apparently reported in terms of all installations in the same location. Thus, it is not clear, for example, what facilities may be included in this database for the location "Norfolk."

However, it is possible to find energy consumption data for Navy shipyards (Table 5). One significant complicating factor in interpreting these data is that ships in dock in shipyards get their energy from the shipyard. This energy consumed by ships, which would not be considered process energy, may comprise a significant and highly variable amount, which may or may not be broken out from the energy used to run the shipyard. Table 5 shows this breakdown of energy consumption where it is available.

2.3.3.2 Pollution Generation. The environmental concerns at Navy shipyards are similar to those at Army and Air Force process installations—used blasting media, paint wastes, solvents, and plating emissions.

Table 5. Energy usage in Navy shipyards.

Shipyard		Gas MBtu*	Oil MBtu	Coal MBtu	Steam MBtu	Total Thermal	Electricity MBtu	Total Energy	Percent Thermal
Portsmouth, NH			891,636			891,636	174,206	1,065,842	83.7
Philadelphia, PA	Shipyard	995,566	17,846			1,013,412	337,365	1,350,777	75.0
	Ships	141,058	406			141,464	71,717	213,181	66.4
	Total	1,136,624	18,252			1,154,876	409,082	1,563,958	
Norfolk, VA	From NPWC				651,532	651,532	558,011	1,209,543	
	Direct purchase	9,007			651,532	660,539	107,540	126,547	49.4
	Total	9,007					665,551	1,336,090	
Charleston, SC		549	115,926		445,734	562,209	228,432	790,641	71.1
Mare Island, CA		642,984				642,984	232,150	875,174	73.5
Puget Sound, WA	Shipyard	78,294	110,606	822,189		1,011,089	647,416	1,658,505	61.0
	Ships	78,294	9,371	49,828		59,199	85,069	144,268	41.0
	Total		119,977	872,017		1,070,288	732,485	1,802,773	
Pearl Harbor, HI	Shipyard		13,494			13,494	159,077	172,571	7.8
	Ships		102,794			102,794	203,756	310,550	33.1
	Total		116,288			116,288	362,833	483,121	
Long Beach, CA	Shipyard	320,229				320,229	212,487	532,716	60.1
	Ships	27,303				27,303	58,216	85,519	31.9
	Sotal	347,532				347,532	270,703	618,235	
Totals		**2,214,990**	**1,262,079**	**872,017**	**1,097,266**	**5,446,352**	**3,075,442**	**8,521,794**	**63.9**

* Data are for FY95 except Norfolk (8/94-7/95); source: Naval Facilities Engineering Service Center, Port Hueneme, CA, except Norfolk.

3 Evaluation of Data From Three Site Visits

Three site visits were conducted in the first task of this project to collect energy and environmental data representative of DOD industrial facilities. These site visits were made to a representative (1) Army base (Anniston Army Depot), (2) Air Force base (Robins Air Force Base), and (3) Naval shipyard (Norfolk Naval Shipyard). The overall objectives of these site visits were to: (1) collect and evaluate available energy consumption/emissions data, (2) directly observe various types of process activities and operations, and (3) examine facility conditions.

3.1 Army Depots (Anniston Army Depot)

From 17-20 July 1995, the project team visited Anniston Army Depot in Anniston, AL, to conduct a site survey of Army industrial processes. Data were reviewed on the total quantities and costs of the various forms of energy consumed annually by Anniston. Although at the present time Anniston has several coal boilers, facility managers at Anniston expressed a desire to replace the use of coal with natural gas. In 1994, Anniston negotiated a new rate structure for electricity from Alabama Power Company that eliminates demand charges, and charges only per kWh; this charge is, however, a function of time of use. The average cost of electricity is about $0.04/kWh. With the new rate structure, Anniston saved $500,000 in 1994 on purchased electricity. Natural gas is purchased on an interruptible basis on a 10-year contract.

Site-wide diagrams of electricity, steam, and compressed-air distribution systems were then reviewed to identify areas of apparent significant consumption (although consumption in individual buildings is not metered).

To get an overview of pollution problems, Anniston's air emissions inventory was reviewed. The primary problems with pollution at Anniston involve emissions from paint booths, and hazardous wastes from blasting booths (paint particles mixed with spent blasting media).

The process areas of particular interest to this project were determined to be the electroplating shop, spray paint booths (of various types and sizes), abrasive blasting,

heat treating, and the industrial wastewater treatment plant. The better part of 2 days of the 4-day visit were then spent in examining in detail each of these process areas. In addition to the process areas, the compressed-air supply building was also toured. Data collected included copies of boiler logs, compressed-air logs, and heat-treating furnace logs. Other information collected included nameplate data, equipment descriptions, motor sizes, process conditions, some measure of process production, operating procedures, and maintenance requirements.

As the result of gathering these data at Anniston, a broader understanding of the variety of processes within certain process categories was obtained. For example, within the general category of spray paint booths, there are large drive-through booths for painting vehicles, with perhaps a preheat oven and a final drying oven, and smaller booths for painting parts, which move through the booth hung on a conveyor and through a drying oven. Such booths may have either a dry filter or a water curtain for particulate control. These different varieties of paint booths have different opportunities for energy and pollution reduction, and hence, it is important to recognize these differences in booth designs. Similarly, there are differences in the heat treating process (i.e., case hardening, tempering, annealing, etc.) for treating iron or steel parts, and similar processes for treating copper or brass.

As the result of collecting the detailed process data and interviewing the process operators, a number of ideas for conserving energy in the process operations were conceived. These ECOs ranged from simple changes in process operating procedures, temporary work-around solutions, and standard recommendations that needed to be reemphasized, to major capital expenditures and research into promising new technologies. These suggestions for ECOs, which are specific to Anniston, are described and analyzed for their potential in the following sections.

3.1.1 Energy and Environmental Data

3.1.1.1 Energy Data. Like most industrial plants, Anniston does not have steam or electric meters at the process or even the building level. Data on energy consumption are available only for the base as a whole in the form of quantities of fuels consumed by month, and hourly data on steam output by boiler. Table 6 lists quantities of fuels purchased by Anniston in recent fiscal years. Energy usage at the process level for the evaluation of ECOs must be estimated using engineering judgment and data on equipment characteristics and specifications obtained from equipment manufacturers.

3.1.1.1.1 Main Boiler Plant (Building 401). The main boiler plant is comprised of five coal-fired boilers (each with a capacity of 30,000 lb/hr of steam generation) and

one gas-fired boiler (capacity of 50,000 lb/hr of steam generation) with oil back-up. Steam is generated for the most part at 150 psi. In 1994 fuels were consumed in the following quantities:

- Coal 9,393.1 tons
- Gas 72.807 million cu ft
- Oil 140.88 thousand gal.

The condition of the steam lines is described as good. However, the boiler logs indicate that a great deal of make-up boiler feedwater is required, with apparently a number of leaks in the condensate return lines, or the condensate not being returned from some process areas.

Table 6. Total facility energy purchases at Anniston Army Depot.

	FY93	FY94
Electricity:		
MWh	62,203	61,676
Cost, $	3,100,373	3,238,026
MBtu	212,299	210,500
Coal:		
Tons	10,547	9,085
Cost, $	685,555	590,504
MBtu	259,244	223,308
Propane:		
Gal	54,184	47,523
Cost, $	43,889	38,494
MBtu	5,201	4,562
Natural Gas:		
Kcf	71,609	102,086
Cost, $	292,713	413,051
MBtu	72,424	103,248
Fuel Oil:		
Gal	na	na
Cost, $	na	na
MBtu	84,298	na

Recent data on steam production from the main boiler plant for a period of 12 months was collected and analyzed on a monthly basis (Table 7). This table shows the quantities of coal, oil, and natural gas consumed each month from October 1993 to September 1994, and the corresponding amounts of steam produced. Almost 70 percent of the energy used to generate this steam came from coal.

3.1.1.1.2 **Air Compressors (Building 402).** Compressed air is generated at Anniston with four 700-hp compressors (each is a four-stage compressor with a capacity of 2300 cfm) and two 600-hp compressors (each is also a four-stage compressor with a capacity of 2300 cfm). Synthetic lubricants are used. There are two dryers for the compressed air. Table 8 shows the estimated compressed-air production at Anniston by month during 1994.

3.1.1.1.3 **Heat Treating Shop (Building 108).** The heat treating shop at Anniston has six ovens and furnaces in use, of different sizes and capabilities. Three are gas-fired, and the others are electric. The most important furnaces are a quench furnace (No. 1) with a controlled atmosphere and a draw furnace (No. 2), which are used for a quench (@1500 to 1600 °F) and temper (@800 to 1200 °F) process. Approximately 60 percent of the current workload through the shop goes through this process.

Table 7. Steam produced and fuel used in main boiler plant (Building 401) at Anniston Army Depot.

Date	Heating Degree Days	Coal Used tons	Steam from Coal Mlb	Oil Used gal	Steam from Oil Mlb	Gas Used Mcf	Steam from Gas Mlb	Total Steam Mlb
10/93	143	456.5	9.947	27,919	2.726	2.804	1.898	14.571
11/93	426	1,182.6	25.775	3,031	0.296	6.817	3.109	29.180
12/93	645	1,670.3	36.412	---	---	13.206	6.223	42.635
1/94	759	1,705.4	37.185	11,712	1.144	12.705	6.432	44.761
2/94	444	1,000.7	21.815	---	---	11.017	4.838	26.653
3/94	371	837.4	18.298	2,885	0.218	13.214	6.761	25.277
4/94	108	492.7	10.740	9,398	0.917	3.942	1.700	13.357
5/94	0	266.7	5.825	32,791	3.202	1.398	0.616	9.643
6/94	0	343.0	7.576	21,419	2.092	2.590	0.988	10.656
7/94	0	224.6	4.900	22,109	2.159	1.436	0.571	7.630
8/94	0	436.1	9.504	21,093	2.060	4.328	1.615	13.179
9/94	0	329.0	7.174	17,593	1.718	4.345	1.556	10.448
Totals*	2896	8,945.0	195.151	169,950	16.532	77.802	36.307	247.990

* Estimated amount of energy:

8,945 tons of coal x 25 MBtu/ton	=	223,625	MBtu (68.8% of total)
169,950 gal of oil x 0.14 MBtu/gal	=	23,793	MBtu (7.3% of total)
77.802 Mcf of gas x 1000 MBtu/Mcf	=	77,802	MBtu (23.9% of total)
		325,220	MBtu/yr

Both of these furnaces are gas-fired with firebrick construction. They are left on all the time to minimize temperature cycling of the firebrick. They are supposedly turned down at night and on weekends, but the quench furnace is not supposed to go below 1400 °F. These gas-fired furnaces exhaust into the atmosphere. Because the quench furnace is heated indirectly with the hot combustion gases, which heat the furnace atmosphere with radiant tube heaters, the exhaust from this furnace is at a high temperature and contains a great deal of heat that may potentially be recovered.

Table 8. Estimated production of compressed air at Anniston Army Depot.

Month (1994)	Stage-Hours Run	Compressed-Air Production (Mcf)*
January	346	11.94
February	552	19.04
March	706	24.36
April	606	20.91
May	568	19.60
June	665	22.94
July	573	19.77
August	878	30.29
September	787	27.15
October	792	27.32
November	732	25.25
December	484	16.70
Total	**7689**	**265.27**

* Maximum capacity with all compressors fully loaded: 6 x 2300 cfm = 13,800 cfm.

Another 35 percent of the workload goes into furnace No. 3, which is gas-fired, to be treated at 400 to 600 °F. The remaining 5 percent goes into furnace No. 6, which is electric and typically heated to 1550 to 2000 °F.

The production log for the heat treating shop indicates that each of these furnaces is currently used no more than a couple of days each week.

***3.1.1.1.4* Paint Booths**. Anniston has a wide variety of paint booths, including, for example: (1) large drive-through booths for painting vehicles, such as reassembled tanks, with a preheat oven and a final drying oven (Building 143), (2) large booths for painting large parts (Building 433), and (3) smaller booths for painting parts, which move through the booth hung on a conveyor and through a drying oven (Building 409). Many of these booths have been converted to use a dry filter for particulate control, although there are two booths with a water curtain.

The most significant consumption of energy in a paint booth is for heating the make-up air that flows through the booth on a once-through basis to remove paint particles and volatile-organic-compound (VOC) emissions. The make-up air is typically heated in steam-heated fan coil units. To exit the booth, the air flows through a dry filter or a water curtain, which removes the paint particles. Compressed air is generally

used in some relatively small amount to power paint spray guns. Different types of spray guns have different requirements for compressed air, both in quantity and pressure. At Anniston, conventional spray guns appeared to be used predominantly. High-volume low-pressure (HVLP) guns are somewhat more efficient in their use of compressed air than are conventional spray guns.

The paint drying ovens are heated with steam to an operating temperature of typically 150 °F.

***3.1.1.1.5* Electroplating Shop (Building 114)**. Types of plating done in the shop include silver, tin, lead-tin, electroless nickel, copper, black oxide for steel, and stainless steel, zinc and manganese phosphate, and hard- and soft-coat anodize, as well as chromium. The main work load is in zinc plating. Energy is consumed primarily in using steam for heating tanks, as well as space heating. However, no tank is heated to over 200 °F with steam. It would appear that 150-psi steam is not required for any application in the plating shop. Some compressed air is used for cleaning parts, but 100-psi air from the central supply is not required for this use.

The rate of rejection of plated parts, which can be a problem in some shops, is reportedly low, primarily due to inspection of the part prior to plating to eliminate the processing of cracked or defective parts.

For cleaning parts prior to plating, Anniston is installing two power washers to replace its vapor degreasers. The power washers use steam to heat the washwater to 180 to 200 °F. One potential productivity problem in switching to using power washers instead of vapor degreasers for cleaning is that the power washers use different racks for the parts instead of plating racks; the cleaned parts will have to be re-racked for plating.

One common method used to reduce heat losses and evaporation from heated tanks is to cover the surface of the hot solution with polypropylene balls. This was done in some of the heated tanks at Anniston, but not all of them.

The use of conforming mat anodes for increased plating efficiency was considered by the plating personnel at Anniston, but was rejected in view of the storage requirements for the anodes. Anniston has purchased a dialysis system for separating chromium from the rinse water on the chrome line, but has not installed it because of a lack of sufficient space for the equipment.

Cadmium plating at Anniston has been replaced by the use of aluminum in an ion vapor deposition process.

***3.1.1.1.6* Abrasive Blasting**. There is a large number of cabinets and booths for abrasive blasting for cleaning and paint removal. Vehicles such as tanks are blasted in several drive-through booths (Building 433). The primary blasting medium used is coal slag, but sand, glass beads, steel shot, and walnut hulls are also used. The blasting media pick up chromium and cadmium from the paint. The dust from blasting operations is collected with baghouses. Most of the blasting operations are carried out for 5 to 6 hours a day and use the central 100-psi compressed air. Blasting on a tank in a large booth is usually done with two workers in the booth, each wearing a protective suit supplied with air that consumes 40 to 70 cfm of compressed air. For blasting large parts, Anniston has an automated rotary blast unit that uses steel shot.

3.1.1.2 Environmental Data. Environmental data were collected from the base environmental coordinator. Anniston's air emissions inventory was compiled by base personnel.

***3.1.1.2.1* Criteria Pollutants from Boilers**. The operation of the boilers in Anniston's main boiler plant resulted in the generation of the following pollutants in 1994:

	Tons
Sulfur Oxides	272.44
Particulates	80.07
Nitrogen oxides	72.26
Hydrocarbons	4.93
Carbon monoxide	25.11

***3.1.1.2.2* Used Blasting Media**. One of the most significant environmental concerns at Anniston is the generation and the disposal of used blasting media, which are generally considered to be hazardous waste because of the contamination with paint chips. Table 9 summarizes the amounts of used blasting media generated at Anniston and estimated to contribute to particulate emissions from the base. The table shows that an estimated 500 tons of blasting media were used at Anniston in 1994 with an estimated 100 tons of particulate emissions from these types of sources.

***3.1.1.2.3* Chromium Emissions**. Chromium emissions from plating operations were calculated using emissions data obtained from a 1994 stack test:

Volume: 1.53×10^6 dry standard cubic feet (DSCF)/hr
Average emission stack test: 2.32×10^{-5} gr/DSCF
Operating time: 24 hr/day, 7 days/wk, 50 wk/yr
Calculated emissions: 0.022 tons/yr.

Table 9. Summary of particulate emissions from abrasive blast units at Anniston Army Depot.

Source ID #	Building	Description of Unit	Blasting Medium	Tons Used	Emissions*
8593	434	Small cabinet	Glass beads	1.425	0.285
9268	114	Rotary table	Green Lightning	29.050	5.810
9271	114	Rotary table	Green Lightning	30.950	6.190
9276	114	Glove box	Glass beads	10.000	2.000
9277	114	Glove box	Glassbeads	12.000	2.400
9392	433	22'x12'x12' walk-in	Walnut hulls	36.100	7.220
9397	409	Rotary blast	Steel shot	1.000	0.200
9398	409	Walk-in booth	Green Lightning	10.000	2.000
9399	409	Walk-in cabinet	Green Lightning	10.000	2.000
9401	409	Glove booth	Glass beads	0.500	0.100
9402	409	Wheelabrator	Steel shot	1.000	0.200
9403	409	Rotary blast	Steel shot	3.050	0.610
9404	409	Rotary blast	Steel shot	2.025	0.405
9427	409	Walk-in	Walnut hulls	25.500	5.100
9432	409	Small glove booth	Glass beads	0.500	0.100
10476	130B	Glove booth	Glass beads	0.500	0.100
10477	130B	Glove booth	Glass beads	0.500	0.100
11155	105	Blast cabinet	Walnut hulls	0.250	0.050
11408	106	Blast cabinet	Walnut hulls	0.725	0.145
11410	106	Blast cabinet	Walnut hulls	0.475	0.095
11938	117	Blast cabinet	Glass beads	0.325	0.065
13136	130	Glove booth	Glass beads	1.000	0.200
17223	114	Wheelabrator	Green Lightning	40.000	8.000
17263	114	Wheelabrator	Green Lightning	40.000	8.000
F2263	114	Rotary table	Glass beads	10.000	2.000
G3383	130	Glove booth	Walnut hulls	11.325	2.265
H8064	409	Roto blast, 8'x8'x15'	Steel shot	1.000	0.200
H8071	128TES	5'x4'x6' glove booth	Glass beads	1.600	0.320
H8701	128TES	8'x4'x7' blast cabinet	Glass beads	3.000	0.600
J0065	409	Walk-in booth	Steel shot	1.000	0.200
J9052	114	Tumbler	Aluminum oxide	4.000	0.800
J9053	114	Tumbler	Glass beads	12.000	2.400
Stack 1	129SA	Several	Green Lightning	180.000	36.000
Stack 2	129SA	Several	Glass beads	18.000	3.600
Totals				498.800	99.760

*Collection efficiency is assumed to be 80% for all control devices. All units are equipped with baghouses; some also have cyclones upstream from the baghouse.

***3.1.1.2.4* Emissions from Gasoline**. There were benzene and VOC emissions from gasoline facilities, which were calculated from AP-42 emission factors for gasoline distribution:

1994 total throughput:	235,796 gal
Total evaporative losses:	1.53 ton
Benzene emissions at 1.2%:	0.02 ton.

***3.1.1.2.5* Hazardous Air Pollutants**. Hazardous air pollutants (HAPs) were generated from paint booths, degreasers, and paint-stripping operations. Emissions of trichloroethylene were generated from six vapor degreasers in the amount of 77.748 tons, with the three largest ones generating 29.462, 21.142, and 10.912 tons each. With the advent in the near future of more stringent regulations affecting vapor degreasers, most of these degreasers will be phased out.

NPX paint stripping accounted for 28.40 tons of methylene chloride emissions.

The use of 14 paint booths accounted for the generation of 31.994 tons of HAPs, in the form of chromium, methylethyl ketone, methylisobutyl ketone, toluene, and xylene. Nonpoint sources contributed an additional 4.252 tons. Emissions from paint booths are broken down in Table 10. This breakdown indicates which paint booths are used the most and which paint products are the most common ones used.

***3.1.1.2.6* Emissions From Open Burning/Open Detonation**. A variety of emissions are generated from open burning(OB)/open detonation(OD) of explosives. These emissions include criteria pollutants such as carbon monoxide, nitrogen oxides, sulfur oxides, and particulates; volatile organic compounds; and HAPs. Emissions are estimated through the use of emission factors and the weight of explosives destroyed.

Open burning, explosives destroyed:	612,060 lb during 1994
Open detonation, explosives destroyed:	103,995 lb during 1994

	Tons	
	OB	OD
Criteria Pollutants	9.97	36.68
VOCs	1.63	1.48
HAPs	4.03	0.42
Total	15.63	38.58

***3.1.1.2.7* Summary**. A summary of the air emissions from Anniston Army Depot for the year 1994 is shown in Table 11.

Table 10. Breakdown of HAP emissions by paint booth and product.

Source ID#	Building	Product #	HAPs, tons: Chromium	Methyl Ethyl Ketone	Methyl Isobutyl Ketone	Toluene	Xylene	Subtotal	Total
4308	433	8010001818079		2.177		1.058	0.498		3.733
4309	433	8010001818079		2.177		1.058	0.498		3.733
9362	433	8010011606742	0.541	0.541		0.541	0.541	2.164	
		6810002812785		1.005				1.005	
		8010013138701		0.046		0.046		0.092	
		6810002900048				0.090		0.090	3.351
9363	433	8010011606742	0.541	0.541		0.541	0.541	2.164	
		6810002812785		1.005				1.005	
		8010013138701		0.046		0.046		0.092	
		6810002900048				0.090		0.090	3.351
9385	409	8010011606742	0.110	0.110		0.110	0.110	0.440	
		6810002812785		0.073				0.073	
		8010013138701		0.113		0.113		0.226	
		6810002900048				0.096		0.096	
		8010001818079		0.882		0.428	0.202	1.512	2.347
9388	409	8010011606742	0.110	0.110		0.110	0.110	0.440	
		6810002812785		0.073				0.073	
		8010013138701		0.113		0.113		0.226	
		6810002900048				0.096		0.096	
		8010001818079		0.882		0.428	0.202	1.512	2.347
11939	117	8010013138701		0.045		0.045		0.090	
		8010001605788			0.169	0.394		0.563	0.653
B5180	106	8010011606742	0.038	0.038		0.038	0.038	0.152	
		8010001605788			0.143	0.334		0.477	0.629
E8484	143A	8010011606742	0.396	0.396		0.396	0.396	1.584	

Source ID#	Building	Product #	HAPs, tons					Subtotal	Total
			Chromium	Methyl Ethyl Ketone	Methyl Isobutyl Ketone	Toluene	Xylene		
		6810002812785		0.447				0.447	
		8010013138701		0.045		0.045		0.090	
		6810002900048				0.027		0.027	
E8486		8010001818079		1.384		0.672	0.316	2.372	4.520
	113	6810002812785		0.151					0.151
G3738	409	8010011606742	0.110	0.110		0.110	0.110	0.440	
		6810002812785		0.073				0.073	
		8010013138701		0.113		0.113		0.226	
		6810002900048				0.096		0.096	
		8010001818079		0.882		0.428	0.202	1.512	2.347
G4122	129	6810002812785		0.184				0.184	
		6810002900048				0.018		0.018	
		8010001818079		0.012		0.006	0.003	0.021	0.223
H2408	433	6810002900048				0.090			0.090
J9041	143A	8010011606742	0.396	0.396		0.396	0.396	1.584	
		6810002812785		0.447				0.447	
		8010013138701		0.045		0.045		0.090	
		6810002900048				0.027		0.027	
		8010001818079		1.384		0.672	0.316	2.372	4.520
Non-point		8010001605788			0.074	0.172		0.246	
		6810002812785		1.290				1.290	
		8010013138701		0.011		0.011		0.022	
		6810002900048				0.144		0.144	
		8010001818079		1.488		0.723	0.340	2.551	4.253
									36.248

Table 11. Summary of air emissions from Anniston Army Depot for 1994.

	Actual Pollutant Emissions (Tons per Year)							
	Particulate	Sulfur Dioxide	Nitrogen Dioxide	Lead	Hydro-carbons	HAPS	Carbon Monoxide	VOC
Point 001 Boiler #1	23.05	77.20	18.98	0.00	1.36		6.78	
Point 002 Boiler #2	18.30	61.29	15.07	0.00	1.08		5.38	
Point 003 Boiler #3	15.96	53.46	13.15	0.00	0.94		4.69	
Point 004 Boiler #4	22.53	75.46	18.55	0.00	1.33		6.63	
Point 005 Boiler #5	0.00	0.00	0.00	0.00	0.00		0.00	
Point 007 Other Misc Sources	100.58	6.70	2.43	0.00	2.28	142.44	4.09	66.70
Point 016 Boiler #6	0.23	5.02	6.51		0.23		1.63	
OB/OD	41.33	0.53	0.75	3.98	0.00	4.45	4.04	3.11
Plant-Wide Total Pollutant Emissions`	221.98	279.67	75.44	3.98	7.21	146.89	33.25	69.80

3.1.2 Analysis of Data

3.1.2.1 Energy Data. The data in Table 6 on total energy use at Anniston shows that the major energy cost is associated with the purchase and use of electricity. On the basis of energy content, however, thermal uses of energy account for the majority of energy use at Anniston—66.5 percent in 1993 versus 33.5 percent for electricity.

The data in Table 7 on monthly production of steam were analyzed to estimate the proportion of steam used for heating and nonheating (i.e., process) uses. Based on the amount of steam used monthly during the nonheating season and assumed to represent an essentially constant process load, it is estimated that approximately 55 percent of the steam generated at Anniston is used for process uses (see Table 12).

Based on data collected and analyzed for Anniston in a previous study (Day and Zimmerman, and SAIC 27 July 1991), the energy consumed at Anniston may be divided into the use categories shown in Table 13.

3.1.2.2 Environmental Data. For those pieces of equipment included in the air pollution source inventory, the environmental data are useful in: (1) indicating what pieces of equipment appear to be used the most, and (2) providing some quantitative measure of use.

For example, Table 14 lists the paint booths that appear to be the most used at Anniston. These booths are the most important to include in an analysis of energy usage and opportunities for energy conservation. The air pollution source inventory lists over 50 booths of a wide variety of sizes and types, but many of them are apparently used very little, if at all. The nine booths listed in Table 14 account for 83 percent of the HAP emissions attributed to paint booths and, by implication, the usage of paint and the energy consumed in painting at Anniston.

Table 12. Analysis of steam usage at Anniston Army Depot.

Season	No. of Months	Total Steam Mlb	Percent of Total Steam	Monthly Average Mlb/mo
Heating	5	168.51	68.0	33.70 (5 mo.)
Nonheating	7	79.48	32.0	11.36 (7 mo.)
Totals	12	247.99	100.0	20.67 (12 mo.)

Process use = 11.36 Mlb/mo x 12 mo = 136.32 Mlb/yr (55.0% of total annual steam)
Heating use = 247.99 Mlb/yr - 136.32 Mlb/y = 111.67 Mlb/yr (45.0% of total annual steam)

Table 13. Analysis of energy consumption at Anniston based on use category.

Use Category	MBtu/yr* 1984-5	Percent Use	MBtu/yr Present**
Electrical		(percent electrical)	
Lighting	37,404	13.7	28,838
Environmental Motors	22,664	8.3	17,472
Process Motors	82,904	30.4	63,992
Welding	3,907	1.4	2,947
Dynamometers	41,050	15.1	31,786
Air Compressors	46,500	17.1	35,996
Misc. Buildings	37,974	13.9	29,260
Steam		(percent steam)	
Process			
Spray Booths	4,222	1.7	4,216
Dryers	8,350	3.3	8,184
Steam Cleaning	4,776	1.9	4,712
Vats	25,143	9.9	24,551
Environmental			
Heating	74,486	29.2	72,413
Ventilation	39,402	15.5	38,438
Power Plant			
Turbines	14,503	5.7	14,135
Make-up Losses	25,418	10.0	24,799
Insulation Losses	29,010	11.4	28,271
Trap Losses	29,657	11.6	28,767
Totals	527,370		458,490

* Data from reference 4.
** Estimated as percent use x latest 12-month total.

Table 14. List of paint booths most used at Anniston Army Depot.

Source ID #	Building	Description	Total HAP Emissions (tons)	Painted Products
E8484	143A	drive-through, 82x22x18-ft dry filter	4.520	final paint of assembled tanks
J9041	143A	drive-through, 78x26x18-ft dry filter; and drying oven	4.520	final paint of assembled tanks
4308	433	drive-through, 25x15x15-ft water wash	3.733	large tank parts
4309	433	drive-through, 25x15x15-ft water wash	3.733	large tank parts
9362	433	drive-through, 25x15x15-ft dry filter	3.351	large tank parts
9363	433	drive-through, 25x15x15-ft dry filter	3.351	large tank parts
9385	409	walk-in booth, 20x10x10-ft dry filter	2.347	tank parts
9388	409	walk-in booth, 20x10x8-ft dry filter	2.347	tank parts
G3738	409	walk-in booth, 20-ft long, dry filter	2.347	tank parts

HAP emissions at Anniston can be reduced with a variety of potential measures. The methylene chloride emissions can perhaps be reduced by finding an alternate solvent for stripping paint. Research in the area of alternate chemical paint strippers is currently being pursued (Day and Zimmerman, and SAIC 8 February 1991).

Trichloroethylene emissions will be reduced significantly with the elimination of most of the vapor degreasers, which are slated to disappear because of more stringent restrictions on the availability and the use of these types of cleaning solvents. To replace the functions of the vapor degreasers, Anniston already has a number of new power washers in place. These use hot water sprayed at pressure through nozzles in a sort of washing machine. The dirt and grease cleaned off the metal parts is automatically skimmed from the wastewater so that the water can be reused.

To reduce HAP emissions resulting from painting operations, which comprise the rest of Anniston's HAP emissions, a low-cost measure requiring no capital expense is simply to train the painters to use the more efficient high-volume low-pressure (HVLP) spray guns properly. On the site visit, the painters were observed diluting the paint with more solvent to make it easier to spray. This use of solvent for dilution probably accounts for some of the recorded use of methylethyl ketone solvent (see Table 15). The use of this solvent should be monitored to make sure that it is used only for necessary purposes. For cleaning operations, a more environmentally acceptable cleaning agent should be found.

The most cost-effective way to reduce the HAP emissions resulting from painting operations is probably to reduce the solvent content of the paints used, rather than to try to capture the emissions. Paint and coating reformulation projects are currently being pursued with this objective (Day and Zimmerman, and SAIC 8 February 1991). Until candidate coatings have been developed to meet requirements, it is not possible to estimate potential reductions in HAP emissions with this approach.

The other major environmental concern at Anniston—the use and the disposal of used, contaminated blasting media—can perhaps be addressed with a variety of potential measures: (1) use of different blasting media leaving no residue other than paint chips (e.g., frozen CO_2 particles) or a residue that is easily separable from paint chips (e.g., high-pressure water jets), or (2) better control of emissions with more efficient collection systems or increased capability to recycle the collected blasting media.

3.1.2.3 Facility Conditions. Another objective of making the site visits in this task was to examine facility conditions. The general impression of the physical condition of the processes at Anniston was that they have been well maintained. Most of the

Table 15. Breakdown of HAP emissions by product.

Product #	HAPs, tons					Total
	Chromium	Methyl Ethyl Ketone	Methyl Isobutyl Ketone	Toluene	Xylene	
8010011606742	2.242	2.242		2.242	2.242	8.968
6810002812785		4.748				4.748
8010013138701		0.577		0.577		1.154
6810002900048				0.774		0.774
8010001818079		11.268		5.474	2.577	19.319
8010001605788			0.386	0.899		1.285
Totals	**2.242**	**18.835**	**0.386**	**9.966**	**4.819**	**36.248**

process equipment observed on the site visit was only a few years old, although some of the paint booths may have been 10 years old. The last two water curtain booths of this vintage are slated for replacement next year with dry filter booths. Some of the heat treating furnaces were of 1970s vintage, but the quench and draw furnaces which are used most often date from 1984. The central air compressors are quite old, but also appear to be well maintained. The central boilers were not observed; some of the old coal-fired boilers are slated to be replaced. The steam lines appeared to be in good shape, with perhaps no more than the usual problems with leaks and the steam traps.

3.1.3 PEPR Opportunities with Estimations of Investment and Savings

As the result of observing the process operations at Anniston and collecting process data, a number of ideas for conserving energy in the process operations were conceived. These ECOs are listed below. Where sufficient information was available for analyzing these ECOs for their potential for Anniston Army Depot, the results of these analyses are also described.

3.1.3.1 Descriptions of ECOs.

3.1.3.1.1 Central Compressed Air System.

1. Compressed air is used in several shops, for example the plating shop, for cleaning (i.e., blowing dust and dirt) and drying parts. The pressure of the central supply, which is 100 psi, is typically throttled to 30 to 40 psi for these types of applications. Since these are low-pressure, low-volume uses of

compressed air and the high pressure of the central supply are not needed, it may be more economical to supply air for these applications from small portable air compressors or blowers located at the application sites—particularly if long runs of compressed-air lines can be shut down.

2. In another application similar to that described in No. 1, only low-pressure compressed air is needed for the air-support function in the rubber suits used by workers in blasting booths. Again, it may be more economical to supply this air from a small portable air compressor or a blower at the site.

3. Locate, measure, and fix leaks in the central system—this is an ECO that must be done on a continuing basis.

4. Survey actual process requirements—air pressure and consumption—for compressed air usage to identify all areas that could perhaps be satisfied with lower-pressure air, such as paint shops, plating shop, some uses in blasting booths, etc. The idea here is to estimate the relative requirements for low- and high-pressure compressed air and see how the different requirements can be segregated. Perhaps it would pay to set up a separate low-pressure compressed-air circuit for those areas requiring only low pressure and dedicate some of the central compressors to low-pressure service.

3.1.3.1.2 Central Steam Supply System.

1. The steam generated in the central boiler house and distributed in the supply system is produced at 150 psi. Before this steam goes to several areas, it is throttled to 80 psi. Steam used in steam cleaning vehicles and parts is used at 80 psi, but whether 80 psi is a requirement for the equipment or is simply what has been used in the past is not clear. The pressure of the steam generated should be lowered to 80 psi, or even lower, and the throttling of the steam should be eliminated.

2. Steam at 150 psi is sent to the plating shop, where the highest required process temperature satisfied by steam is 265 °F (the equivalent temperature of 40-psi steam) for a single vat. The pressure of the steam sent to the plating shop should be lowered if possible.

3. There is a steam line to several buildings beyond the plating shop that could be turned off whenever heat is not needed, except for an unknown, probably small requirement for steam for humidifying one small area. Some other way should be found, such as a small package boiler, to supply the needed steam for

this purpose. An even better solution may be to move the process or room requiring humidification to some location requiring year-round steam.

3.1.3.1.3 Spray Paint Booths.

1. Investigate the use of electrostatic painting to reduce the amount of overspray and hence the amount of particulate that: (1) is wasted and (2) must be collected by the dry filters.

2. The operators seem to use a wide variety of pressures for painting. Unless the necessary pressure for operating the spray guns depends on the kind of paint, the requirements for air pressure for spray painting should be standardized at the lowest level. Actual requirements should be surveyed, standardized procedures developed (for different paints, if necessary), and the operators trained to use the specified pressures.

3. For ease of application, perhaps, the operators sometimes add extra solvent to the paint. This practice negates the advantages of using paints with low volatiles content. The operators should be trained in the use of low-volatile-content paint so that they will not add extra solvent to it.

4. Consider the use of high-volume low-pressure (HVLP) spray guns—for energy conservation, reduced paint usage through a greater transfer efficiency (the main benefit), less pollution (less paint waste, and fewer VOCs emitted to the atmosphere), and less frequent changing of the dry filters with lower costs. The use of HVLP guns should be investigated for specific types of paints and specific paint booths. These guns are slower to use so that any effects on productivity should be included in the analysis.

5. To confine the warm air in a paint drying oven, the flow of heated air in the oven should be balanced.

6. Consider the use of warm exhaust air from a preheat oven, which is used in the wintertime to warm up cold tanks so that they can be painted, as the makeup air for the drying oven in the line. Filter this air if there is concern for possible particulate matter (dirt).

7. Consider the use of drying oven exhaust air for heat recovery, such as heat exchange with the incoming air. Although the presence of paint particulates in the drying oven exhaust may be of concern for potentially clogging a heat exchanger, the drying oven exhaust air perhaps contains only a small amount.

8. Decrease the amount of air circulation. The specifications for air circulation for an operating booth are generally subject to regulations regarding minimum air flow. However, since the booth was originally designed, the air circulation system may not have been maintained, and the amount of air being circulated may be more than is required. The fans may be oversized and circulate more air than necessary. In addition, if low-volatile-content paints are being used, less VOCs are being emitted that have to be ventilated from the booth. Thus, the amount of air being circulated should be measured and controlled to the minimum, perhaps using a sensor.

9. Install automatic dampers to close the exhaust ducts. Whenever the air circulation system in the booth is turned off, there is a draft through the open ducts to lose heat. Automatic dampers should be installed in the exhaust ducts to close them off whenever the exhaust fans are not running.

10. Use different types of coatings. The operation of spray paint booths can be improved significantly with the introduction of new and different types of paints or coatings, which may have fewer emissions or better quality, or lead to greater productivity. The type of paint used in a spray paint booth might have a significant effect (either positive or negative) on energy usage as well as a significant impact on emissions. For example, the use of powder coatings, waterborne paints, or radiation-cured coatings could reduce VOC emissions significantly, but lead to greater energy usage by requiring the use of ovens for baking, drying, or curing. The use of a newer paint or coating in an existing spray paint booth would have to be researched to determine if the booth could handle such a coating. In addition, research and development would be required to investigate the use of newer coatings for military applications and to change product specifications affected by the use of such coatings.

11. Fix the robotic painting system to standardize the process and the amount of paint used for the specific types of objects to be painted. The problem with using the system in the past was that the paint dried in the supply lines. Perhaps this problem can be mitigated by cooling the paint or the supply lines, by using less catalyst in the mixed paint, by using larger supply lines, or by using higher pressure on the supply lines to move the paint faster through the lines, etc. Energy could be saved in the operation of a robotic paint booth because 100-percent heated make-up air would not have to be supplied.

***3.1.3.1.4* Heat Treating.**

1. Consider recovering waste heat from the hot exhaust streams from the heat treating furnaces and ovens. Of particular interest in this regard are the hot flue gases from the No. 1 furnace at Anniston, which is indirectly heated with gas. The exhaust has a high temperature, typically around 1600 °F, and thus contains a great deal of heat that is now lost to the atmosphere. In addition, this furnace is left on 24 hours a day, 7 days a week, for the most part, to minimize the temperature cycling of the firebrick. The most cost-effective system for capturing some of the waste heat in the exhaust is to install a recuperator to preheat the combustion air. The furnace manufacturer makes recuperators for this furnace for this purpose, which are sold as an option.

2. Consider getting a small oven with a controllable atmosphere with quench capability for heat treating small parts, rather than tying up the large oven with small batches. However, if the large quench furnace remains underused and must be kept fired up, there would appear to be little incentive to procure another furnace of the same type.

3. Schedule production and leave unneeded furnaces turned off. At Anniston, all the heat treating furnaces are typically turned up from their weekend temperatures the first thing on Monday morning to be at operating temperature at all times during the week whenever a job is received. (At the end of the work shift, they may be turned down somewhat, depending on each furnace's characteristics.) If it were known ahead of time what jobs would be received during that day or week, then furnaces not needed for the anticipated production load could be left off, thus saving a great deal of energy without any capital expenditure. Because the quench and temper furnaces appear to be used typically only a couple of days each week for jobs, remaining idle the rest of the time at operating temperature, consider leaving these furnaces turned down on their weekend schedule on Mondays and Tuesdays until this production capacity is needed.

4. Install improved seals on furnace doors. Since a furnace operates at a temperature higher than ambient, air may be drawn into the combustion chamber through any cracks and crevices due to the stack effect. Such air allowed to infiltrate into the furnace is detrimental to the furnace efficiency. Energy can be saved through the use of effective door seals. The quench and the draw furnaces are analyzed separately for this ECO because they operate at considerably different average temperatures.

5. Design heat recovery system to use hot exhaust for preheat. Heat can conceivably be recovered from hot furnace exhaust gases by using them to preheat cold charges before heat treatment. The hot exhaust gases would be ducted into an insulated chamber containing the cold charge before being loaded into the furnace. The same type of insulated chamber could be used to prevent heat losses from hot charges (works-in-process) from being dissipated into the shop atmosphere between processes. A system is analyzed here for the quench furnace because its exhaust is at a much higher temperature than that of the draw furnace.

6. Apply ceramic coating to firebrick. Spray-on ceramic coatings can increase the surface emissivity of the refractory surface to above 0.95. The increased radiative transfer resulting from this increased emissivity can yield savings in fuel. Although such savings cannot be accurately quantified, energy savings from this measure are conservatively estimated as 15 percent of burner fuel input. Quench and the draw furnaces are analyzed separately for this ECO because they operate at considerably different average temperatures.

7. Consider converting electric ovens/furnaces to natural gas. Gas-fired furnaces can be cheaper to operate than electrical furnaces because thermal energy obtained from gas is cheaper than that obtained via electricity.

8. Use full loads in furnaces. Since the amount of energy required to keep a furnace at a constant temperature is not a function of the load inside, the amount of energy per unit of material treated can be reduced by putting a full load in the furnace, rather than only a partial load. For example, for two jobs of half a furnace load apiece, rather than one full-load job, the furnace must be run for two cycles rather than only one. For the type of furnace that is always left on, such as the gas-fired furnaces used for quench and temper at Anniston Army Depot, using a full load is not so important. In a job type of heat-treating shop, the objects in the shop to be treated at any one time may require different conditions, so that it may be difficult to consolidate different jobs to always have a full load. However, this situation could be helped if production were scheduled with this principle in mind, rather than simply treating every job whenever it is received in the shop.

9. Use newer types of furnaces for heat treating. For heat treating metals, there are newer types of ovens and furnaces that may be used. These newer systems, which include induction and indirect resistance furnaces, are more energy-efficient and therefore should be evaluated for possible application to Army processes.

3.1.3.1.5 Electroplating Shop.

1. Float polypropylene balls or use lids on top of solutions to reduce heat losses. Uncovered, hot solutions in plating tanks can lose a significant amount of energy through increased evaporation and heat loss. Balls floated on top of the hot solutions or the use of moveable lids in heated tanks can reduce these heat losses by a significant amount (a factor of perhaps half).

2. Rehabilitate the insulation on heated and cooled tanks, some of which appeared to be coming off the tank walls, etc.

3. Eliminate the use of steam for heating tanks and replace it with natural gas. The use of steam—particularly the 125 to 150 psi steam from the central steam supply with all of the inefficiencies of that system—is an inefficient and unnecessary way to heat the solutions in plating tanks. Systems are available to use natural gas for heating plating tanks directly, with an individual burner system and temperature control for each tank. The other major use of steam in the electroplating shop is for space heating. This use of steam can be eliminated by using gas-fired, infra-red radiant heaters for space heat.

4. Replace air agitation with electric agitation in tanks. Compressed air is typically used for agitating solutions in plating tanks. Although the use of compressed air for this purpose is convenient, compressed air is a very inefficient way to use energy. Air agitation also increases heat losses from heated tanks and the formation of mist. Electric agitators should be considered to eliminate the use of compressed air for agitating the baths.

5. Reduce 100-percent overplating. Frequently, parts are overplated up to 100 percent to allow for an adequate thickness for uniform grinding. However, this amount of overplating would appear to waste energy and materials; overplating should be controlled at a lower level—say, 50 percent—for conservation.

6. Install plating waste concentrators to recover and recycle waste solutions. Waste plating solutions are usually sent to the industrial wastewater treatment plant. These solutions could be recycled by concentrating them; the concentrate is returned to the plating tank and the water is returned to the rinse tank.

7. Replace use of central compressed air with low-pressure air. Compressed air is used in plating shops for a variety of uses, such as cleaning and drying parts, and especially for agitating the tanks. However, these uses do not require 100-

psi air from the central compressed-air supply. Central compressed air is typically throttled before it is used in plating shops. It would be more efficient to generate low-pressure compressed air—for example, with a simple blower—on site within the shop for any necessary use of compressed air.

8. Install automatic dampers to close exhaust ducts. There typically are a large number of exhaust fans and ducts in a plating shop; each hot tank has a ventilation duct that collects fumes and emissions. However, whenever a tank is unused and its fan is turned off, a draft through the open duct causes energy to be lost. A damper that closes automatically if the fan is de-energized would prevent this draft loss.

9. Install variable frequency drives on exhaust ducts. The ventilation load in a plating shop varies as a function of how many tanks are being used at any one time. It is inefficient and wastes energy to keep the ventilation fan running at a constant speed. If the fan is equipped with a variable frequency drive, the fan speed could vary in response to the load, saving energy.

***3.1.3.1.6* Miscellaneous**.

1. At present, rainwater gets into the industrial wastewater system in the steam cleaning areas, causing a surge in the volume of this wastewater to be treated. Prevent the rainwater from getting into this waste steam to minimize these surges in wastewater volume.
2. Implement a continuous monitoring system in the industrial wastewater treatment system to determine the proper quantities of chemicals—polymer, alum, lime, etc.—to be added rather than rely on the experience of the operators to do this manually.
3. Segregate the collection of hazardous and nonhazardous wastes from blasting booths by using different collection boxes, trucks, and collection procedures. (The cost of disposing of a pound of hazardous waste, $0.13/lb, is twice that for a pound of nonhazardous waste, $0.065/lb.)
4. Investigate the possible application to Anniston of new technologies for blasting for paint removal, or cleaning (replacement for steam cleaning), using frozen CO_2 particles. (The CO_2 particles evaporate, leaving only the paint particles, or dirt, for disposal, instead of a large amount of used blasting media combined with the hazardous paint, or washwater from condensed steam.)
5. A 1-million gal water tank containing a reservoir of water for fire protection has a couple of leaks totaling upwards of around 50,000 gal a day. The tank cannot be taken out of service for repair without implementing a substitute or temporary system to provide fire protection. To temporarily control the

water leak (and reduce its cost by minimizing the cost of continually replenishing the tank), design a containment system for the leak for collecting the water and pumping it back into the tank.

6. If the old coal-fired boilers are to be replaced anyway, consider cogeneration in designing the new gas-fired boilers (i.e., design them for a higher temperature and pressure for maximum efficiency in generating electricity).

3.1.3.2 Analyses of ECOs. The ECOs that were identified for Anniston Army Depot for those process areas visited during the site visit, and analyzed are listed in Table 16. Other process ECOs evaluated in a previous study (Day and Zimmerman, and SAIC 27 July 1990) are also included so that they could be recommended to other Army bases. The results of the analyses are also shown in the table. ECOs for which insufficient information was available for their analysis are listed in Table 17.

3.1.4 Prioritized List of Recommendations for Army Bases to Implement

Table 18 is a prioritized list of the ECOs evaluated for Army bases, based on Anniston. Table 18a is prioritized with respect to annual energy savings and 18b with respect to payback period.

It is tempting to add these annual energy savings together to arrive at a grand total, but such a figure should be interpreted with care. There are significant overlaps in the estimates, especially between the savings that could be achieved by overhauling the central steam distribution system (fix traps and leaks, etc.) and the savings to be achieved by ECOs more closely associated with process use. The latter estimates include the savings in lost steam by decreasing the amount of steam sent to the processes. Therefore, if the steam system is repaired to reduce these losses, the process savings may be overstated somewhat.

Excluding for the moment the savings that could be achieved by overhauling the central steam distribution system, the sum total of all other process ECOs saving thermal energy is 75,546 MBtu/yr, to be compared to a total of 331,118 MBtu of thermal energy consumed annually by Anniston (see Table 6)—about 23 percent. The sum total of process ECOs saving electricity is 17,595 MBtu/yr, to be compared to a total of 210,500 MBtu of electricity consumed annually by Anniston—about 8 percent. The total energy savings are about 93,141 MBtu/yr, to be compared to a total energy consumption of 541,618 MBtu—about 17 percent.

Table 16. Summary and evaluation of process ECOs at Anniston Army Depot.

Description of ECO	Capital Cost ($)	O&M Saving ($/yr)	Energy Saving MBtu/yr	Payback yr	Return on Investment %	Savings-to-Investment Ratio (SIR)	Classification and Remarks
Heat Treating Shop							
Install improved seals on furnace doors (quench furnace).	4,600	na	59	16.0	5.4	1.31	Process design modification
Apply ceramic coating to firebrick (quench furnace).	12,600	na	1,174	2.2	16.4	9.57	Process design modification
Apply ceramic coating to firebrick (draw furnace).	12,600	na	456	5.6	11.0	3.71	Process design modification
Install recuperators on gas-fired (indirectly heated) furnace (quench furnace).	13,000	na	929	2.9	14.9	7.34	Process design modification
Schedule production and leave unneeded furnaces turned off -- for example, leave both furnaces at ANAD turned down two extra days per week.	0	na	1,060	---	---	---	Operational modification
Electroplating Shop							
Reduce 100-percent overplating (to compensate for grinding) to 50 percent.	na	na	466[1] 736[2]	---	---	---	Operational modification
Replace air agitation with electric agitation in tanks.	140,000	na	3,128[1] 4,320[2]	5.8	9.2	2.6	Technology replacement
Float polypropylene balls on top of solutions to reduce heat losses.	2,500	na	5,568[1] 12,080[2]	0.1	75.4	186.6	Operational modification

Description of ECO	Capital Cost ($)	O&M Saving ($/yr)	Energy Saving MBtu/yr	Payback yr	Return on Investment %	Savings-to-Investment Ratio (SIR)	Classification and Remarks
Eliminate the use of steam for heating tanks and replace with natural gas (install small natural gas burner on each tank requiring heating).	155,000	na	-1,497[1] 14,243[2]	20.9	0.0	-0.5	Process design modification --energy is saved, but economics poor because gas is substituted for coal (dependence on coal not common at AMC bases)
Improve chrome plating process by revising anode/cathode spacing and reducing plating time [4].	9,120	40,000	14,396	0.2		44.5	Process design modification
Add controls to turn on and schedule vat operations [4].	124,500	16,700	6,705	7.4		1.41	Control technology addition
Spray Paint Booths							
Decrease the amount of air circulation with the use of HVLP spray guns (less overspray and fewer emissions). (9 booths)	0	na	9 x 624[1] 9 x 1,387[2] (12,483[2])	---	---	---	Operational modification
Consider the use of HVLP spray guns for energy conservation, reduced paint usage, less pollution, and less frequent changing of dry filters. (9 booths)	9 x 285 (2,565)	9 x 21,800 (196,200)	9 x 12[1] 9 x 16[2] (144[2])	0.0	48.0	1148	Technology replacement
Consider converting water-wash booths (2) to a dry filter.	2 x 1,670 (3,340)	2 x 22,451 (44,902)	2 x 240 (480)	0.1	74.9	180.5	Technology replacement
Install automatic dampers to close the exhaust ducts when fans are de-energized. (9 booths)	9 x 6,700 (60,300)	na	9 x 598[1] 9 x 1,329[2] (11,961[2])	1.9	16.5	9.7	Control technology addition

Description of ECO	Capital Cost ($)	O&M Saving ($/yr)	Energy Saving MBtu/yr	Payback yr	Return on Investment %	Savings-to-Investment Ratio (SIR)	Classification and Remarks
Central Steam Supply System							
Install orifice-type steam traps in steam mains to allow condensed water to be drained from lines [4].	31,000	13,400	5,080	2.3		4.5	Process design modification
Repair leaks and bad traps in steam and condensate lines [4].	40,000	110,500	45,626	0.4		21.3	Operational modification
Return steam condensate from Buildings 114 and 409 [4].	31,200	22,200	9,197	1.4		7.5	Process design modification
Central Compressed Air Supply System							
Maintain compressed air distribution system with annual program [4].	26,400	7,730	1,972	2.2		2.06	Operational modification
Miscellaneous							
Replace electric motors with energy-efficient types when motors need to be removed for maintenance or replaced [4].	121,400	49,200	7,987	2.5		3.66	Technology replacement
Install variable frequency drives to reduce power inputs to motors at reduced loads [4].	64,000	12,050	1,956	5.3		1.69	Process design modification

[1]Energy saved at the process.
[2]Energy saved in primary fuel, considering losses in central steam and compressed-air supply systems, and efficiency of steam generation.

Table 17. Summary of additional potential process ECOs at Anniston Army Depot.

Description of ECO	Classification and Remarks
Heat Treating Shop	
Use full loads in furnaces.	Operational modification
Provide regular maintenance for gas-fired furnaces.	Operational modification
Consider converting electric ovens/furnaces to natural gas.	Fuel substitution
Determine if the standard amount of exhaust and make-up air provided for in the oven design can be reduced.	Process design modification
Search for a possible need for thermal energy to supply by heat-exchanging with the hot exhaust from the oven.	Process design modification
Review standard operating procedures to see if the recommended heat-treatment temperature and time to produce the desired quality in the product can be reduced.	Operational modification
Investigate the possible use of newer types of ovens.	Technology replacement
Electroplating Shop	
Consider the use of a small blower or portable air compressor (with VFD) in the shop to supply air for cleaning (i.e., blowing dust and dirt) and drying parts (100-psi air from central supply is not needed).	Process design modification
Install automatic dampers to close exhaust ducts when exhaust fans are de-energized.	Control technology addition
Install variable frequency drives on exhaust fans.	Process design modification
Optimize batch size (or use small tanks for small batches).	Operational modification
Install plating waste concentrators to recover and recycle plating solutions.	Technology replacement
Consider installing countercurrent rinsing systems to conserve washwater.	Technology replacement
Rehabilitate the insulation on heated and cooled tanks, some of which appeared to be coming off tank walls.	Process design modification
Consider using conforming mat anodes.	Technology replacement
Consider using more efficient process chemistries.	Technology replacement
Spray Paint Booths	
Investigate the concept of developing a suitable heat-exchange system for exchanging heat from the warm exhaust air to the cold incoming makeup air.	Process design modification

Description of ECO	Classification and Remarks
The air pressure used for spray painting, which seems to vary a great deal, should be standardized at lowest levels; develop standardized procedures (for different paints) based on actual requirements, and train the operators to use the specified pressures.	Operational modification
Consider the use of drying oven exhaust air for heat recovery, such as heat exchange with incoming air.	Process design modification
Consider using warm exhaust air from a preheat oven, used in wintertime to warm up cold tanks before they are painted, as makeup air for the drying oven.	Process design modification
Fix the problems with the robots used in the past for painting; problem: the paint dried in the supply lines; develop a robotic system for the specific types of objects to be painted to standardize the process and the amount of paint used.	Technology replacement
Investigate the use of electrostatic painting to reduce amount of overspray and the amount of particulate which (1) is wasted and (2) has to be collected.	Technology replacement
Evaluate the use of alternate, less hazardous (lower VOC content) paints.	Technology replacement
Investigate the use of newer alternative paints and coatings.	Technology replacement
Train the operators in the use of low-volatile-content, high-solids-content paint so that they will not (1) add extra solvent to it or (2) use more paint than is necessary.	Operational modification
Central Steam Supply System	
Optimize boiler pressure at lower levels using point-of-use pressure control with summer setback (0.1-0.2% savings/10 psi drop). (There appears to be no legitimate need for 150-psi steam in the entire base. The steam pressure is usually throttled to 80 psi at point-of-use anyway.)	Operational modification
Replace steam space heaters in most buildings with direct gas-fired unit heaters (rotary convection and infra-red).	Technology replacement
There is a steam line to several buildings beyond the plating shop which could be turned off whenever heat is not needed, except for an unknown, probably small requirement for steam for humidifying one small area. Find some other way, such as a small electric boiler, to supply the needed steam for this purpose, and block off the central steam line whenever heat is not needed. Better yet -- move the process or room requiring humidification to some location requiring year-round steam, and block off the line in the non-heating season.	Operational modification
Steam at 150 psi is sent to the plating shop, where the highest required process temperature satisfied by steam is 265°F (the equivalent temperature of 40-psi steam) for a single vat. Lower the pressure of the steam sent to the plating shop.	Operational modification
Although it is planned to replace the old coal-fired boilers, this potential project should be deferred until all significant measures to reduce steam consumption have been studied. New boilers may not be needed.	Operational modification

Description of ECO	Classification and Remarks
Decommission and/or idle selected segments of the steam system where piping runs in parallel or users are fed from two directions.	Operational modification
Central Compressed Air Supply System	
Optimize pressure of compressed air at lower levels using point-of-use pressure control (1% savings/2 psig drop).	Operational modification
Survey actual process requirements -- air pressure and consumption -- for compressed air usages to identify all areas which could perhaps be satisfied with lower-pressure air, such as paint shops, plating shop, some uses in blasting booths, etc. It might pay to set up a separate low-pressure compressed-air circuit for those areas requiring only low pressure and dedicate some of the central compressors to low-pressure service.	Operational modification
Switch hand tools from pneumatic to electric (battery or cord) where possible.	Technology replacement
Implement a continuous monitoring system in the industrial wastewater treatment system to determine proper quantities of chemicals -- polymer, alum, lime, etc. -- to be added rather than rely on experience of operators.	Control technology addition
Add 'soft start' to all motors on presses, shears, punches, etc. which have surge load/unload characteristic loads to permit motor downsizing, resulting in higher motor efficiencies.	Control technology addition
Add 'Nortic' power factor controllers on motors on presses, shears, punches, to give higher power factors.	Control technology addition
Blasting Booths	
Segregate the collection of hazardous and nonhazardous wastes from blasting booths by using different collection boxes, trucks, and collection procedures. (The cost of disposing of a pound of hazardous waste, $0.13/lb, is twice that for nonhazardous waste, $0.065/lb.)	Operational modification
In blasting booths only low-pressure compressed air is needed for the air support function in the rubber suits used by workers in blasting booths. It may be more economical to supply this air from a small portable air compressor or blower at the site.	Process design modification
Steam Cleaning	
Rainwater gets into the industrial wastewater system in steam cleaning areas to cause a surge in volume of this wastewater to be treated. Prevent the rainwater from getting into this waste stream to minimize these surges in wastewater volume.	Process design modification
Steam at 80 psi is used in steam cleaning vehicles and parts, but whether 80 psi is a requirement for the equipment or is simply what has been used in the past is not clear. Optimize the steam pressure for steam cleaning, and eliminate the throttling.	Process design modification

Table 18. Prioritized list of process ECOs for Army bases.

Description of ECO	Annual Energy Savings (MBtu*)
a. Annual Energy Savings	
Repair leaks and bad traps in steam and condensate lines [4].	45,626
Improve chrome plating process by revising anode/cathode spacing and reducing plating time [4].	14,396
Eliminate the use of steam for heating tanks and replace with natural gas (install small natural gas burner on each tank requiring heating). (Should be considered by bases not using coal)	14,243
Decrease the amount of air circulation with the use of HVLP spray guns (less overspray and fewer emissions). (9 booths)	12,483
Float polypropylene balls on top of solutions to reduce heat losses.	12,080
Install automatic dampers to close the exhaust ducts when fans are de-energized. (9 booths)	11,961
Return steam condensate from Buildings 114 and 409 [4].	9,197
Replace electric motors with energy-efficient types when motors need to be removed for maintenance or replaced [4].	7,987
Add controls to turn on and schedule vat operations [4].	6,705
Install orifice-type steam traps in steam mains to allow condensed water to be drained from lines [4].	5,080
Replace air agitation with electric agitation in tanks.	4,320
Maintain compressed air distribution system with annual program [4].	1,972
Install variable frequency drives to reduce power inputs to motors at reduced loads [4].	1,956
Apply ceramic coating to firebrick (quench furnace).	1,174
Schedule production and leave unneeded furnaces turned off -- for example, leave both furnaces at ANAD turned down two extra days per week.	1,060
Install recuperators on gas-fired (indirectly heated) furnace (quench furnace).	929
Reduce 100-percent overplating (to compensate for grinding) to 50 percent.	736
Consider converting water-wash booths (2) to a dry filter.	480
Apply ceramic coating to firebrick (draw furnace).	456
Consider the use of HVLP spray guns for energy conservation, reduced paint usage, less pollution, and less frequent changing of dry filters. (9 booths)	144
Install improved seals on furnace doors (quench furnace).	59

Description of ECO	Annual Energy Savings (MBtu*)
b. Payback	
Decrease the amount of air circulation with the use of HVLP spray guns (less overspray and fewer emissions). (9 booths)	–
Schedule production and leave unneeded furnaces turned off -- for example, leave both furnaces at ANAD turned down two extra days per week.	–
Reduce 100-percent overplating (to compensate for grinding) to 50 percent.	–
Consider the use of HVLP spray guns for energy conservation, reduced paint usage, less pollution, and less frequent changing of dry filters. (9 booths)	0.0
Consider converting water-wash booths (2) to a dry filter.	0.1
Float polypropylene balls on top of solutions to reduce heat losses.	0.1
Improve chrome plating process by revising anode/cathode spacing and reducing plating time [4].	0.2
Repair leaks and bad traps in steam and condensate lines [4].	0.4
Return steam condensate from Buildings 114 and 409 [4].	1.4
Install automatic dampers to close the exhaust ducts when fans are de-energized. (9 booths)	1.9
Maintain compressed air distribution system with annual program [4].	2.2
Apply ceramic coating to firebrick (quench furnace).	2.2
Install orifice-type steam traps in steam mains to allow condensed water to be drained from lines [4].	2.3
Replace electric motors with energy-efficient types when motors need to be removed for maintenance or replaced [4].	2.5
Install recuperators on gas-fired (indirectly heated) furnace (quench furnace).	2.9
Install variable frequency drives to reduce power inputs to motors at reduced loads [4].	5.3
Apply ceramic coating to firebrick (quench furnace).	5.6
Replace air agitation with electric agitation in tanks.	5.8
Add controls to turn on and schedule vat operations [4].	7.4
Install improved seals on furnace doors (quench furnace).	16.0
Eliminate the use of steam for heating tanks and replace with natural gas (install small natural gas burner on each tank requiring heating). (Should be considered by bases not using coal)	–

*Estimates of energy savings for application of ECOs to Anniston Army Depot.

If the savings that could be achieved by overhauling the central steam distribution system are included (recognizing that there is some overlap with process savings) the sum total of thermal energy savings is 135,449 MBtu/yr, to be compared to a total of 331,118 MBtu of thermal energy consumption—about 41 percent. The total energy savings are about 153,044 MBtu/yr, to be compared to a total energy consumption of 541,618 MBtu—about 28 percent.

Note that this list of ECOs is by no means comprehensive. Table 17 contains a number of suggestions that could not be quantified at the present time. A number of these opportunities, which should be evaluated in detail at a later date with additional information, should lead to additional energy savings.

3.2 Air Force Logistics Centers (Warner Robins Air Logistics Center)

From 7-11 August 1995, the project team visited Robins Air Force Base (RAFB) in Warner Robins, GA, to conduct a site survey of Air Force industrial processes. The Warner Robins Air Logistics Center (WRALC) at RAFB manages the Air Force's fleets of F-15 fighters, and C-130 and C-141 transports, overhauling and rebuilding them as needed. It also looks after the Air Force's helicopter fleet and airborne tactical missiles. The Avionics Center performs maintenance on over 300 types of Air Force avionics systems. Other systems managed at Warner Robins ALC include vehicles, propellers, automatic data processing equipment, life support systems, hand guns, and bearings. Thus, RAFB's industrial processes are mainly concerned with airplane maintenance and overhaul, including paint stripping, cleaning, and repainting of aircraft mechanical and structural components, stripping and re-plating of metal parts, and the manufacture and the repair of electronic printed circuit boards.

Natural gas (interruptible) is used as the main fuel with fuel oil as backup. RAFB enjoys relatively low average rates for electricity ($0.04/kWh). RAFB has been actively engaged in implementing a number of energy management measures and has succeeded in reducing energy consumption considerably—annual reductions in energy consumption of 5 and 6 percent over the last 2 years from the 1990 baseline. Of 13 bases in the Air Force Materiel Command, RAFB has gone from thirteenth to fourth in terms of meeting its energy consumption goals.

RAFB's electric utility, Georgia Power Company, is cooperating with RAFB in a program to install electrical meters on individual buildings (over 300 meters by the time that the program is complete) and to monitor the meters and collect data via a real-time computer system using Georgia Power's EnerLink software. Each meter

costs about \$2300. The total capital cost of the EnerLink system is about \$800K; maintenance cost over the next 10 years will be another \$800K. Meters are also being installed on chilled-water lines (11 meters at a cost of \$92K). There are also some steam meters. Electricity accounts for half the energy consumption and 75 percent of the energy cost.

RAFB has a comprehensive direct-digital-control (DDC) system for monitoring and controlling energy consumption for space conditioning in individual buildings. This system has been very effective in cutting energy usage in buildings over the past couple of years. RAFB has no electrical demand charge but does have real-time pricing of electricity. On some days in the middle of summer when Georgia Power must use expensive peak-power generation, RAFB is faced with \$0.30/kWh electricity, making it worthwhile to fire up their diesel generators to generate electricity on site (at a cost of \$0.12/kWh to save \$0.18/kWh).

At an initial meeting with the heads of several departments (infrastructure, environmental management, process engineering, civil engineering), the data collection needs of the project were discussed. Processes being carried out at RAFB were described, and it was decided to survey their heat treating processes, plating, aircraft corrosion control and depainting operations, and parts cleaning and painting. One significant problem with their (two) central steam supply and distribution systems is that summertime loads are relatively low compared to the capacities of the boilers. Under consideration is the idea of tying the two steam plants and distribution systems together (at an estimated cost of more than \$1 M) so that boilers can be more fully loaded.

Steam is generated at 125 psi. Although steam is not needed at anywhere near this pressure, the steam plant people would be reluctant to reduce the steam pressure, citing the pressure drop through long lines and the need to maintain a pressure reserve in the steam distribution system when boilers go down. In the latter situation, if the steam pressure drops below, say, 80 psi, the lines fill with condensate, and the whole steam system goes down. Purging the steam lines of water is a big problem, to be avoided.

The better part of 3 days was spent in examining in detail each of the process areas of interest. In addition to the general process areas, the central steam and chilled-water plant, compressed-air supply building, and industrial wastewater treatment plant were also examined. Data collected included copies of the energy consumption data and EnerLink plots for individual buildings for the process areas. Other information collected in the detailed examination of the processes, where possible, included nameplate data, equipment descriptions, motor sizes, process conditions,

some measure of process production, operating procedures, and maintenance requirements. For individual pieces of equipment in most cases, it is necessary to contact equipment manufacturers for equipment specifications and energy consumption.

As the result of gathering these data at Robins, a broader understanding was gained of the variety of processes within certain process categories and, of course, the differences between Army and Air Force processes. Data were collected on a variety of processes, mainly in the general categories of spray paint booths, heat treating, electroplating, and abrasive blasting. Data were collected also on a process that is perhaps unique to the Air Force—the repair of airplane radomes. However, this process involves the standard operations of depainting, sanding, and painting. A number of the heat treating, depainting, and painting processes at Robins Air Force Base were found to be quite different from those carried out at Anniston Army Depot. Different materials and process conditions are involved in the Air Force processes.

For example, within the general category of spray paint booths, in the Air Force there are large hangar-size booths for painting airplanes, with the hangars being air conditioned with once-through air because it is thought that the temperature or the humidity should be controlled for better paint quality. There are also standard smaller booths for painting parts, which are put onto carts and wheeled into the booth for painting and out of the booth for drying under ambient conditions. Such booths may have either a dry filter or a water curtain for particulate control. These different varieties of paint booths have different opportunities for energy and pollution reduction, and hence, it is important to recognize these differences in booth designs and operations. Similarly, there are differences in heat treating processes for treating iron or steel parts, and similar processes for treating aluminum parts (obviously important for airplanes).

As a result of the visit to RAFB, the site-visit team recommended a number of energy conservation opportunities to Robins in their industrial processes. Because the processes conducted at RAFB are low-temperature processes using relatively little thermal energy, there is generally no waste heat that could be recovered. The recommendations tended to focus on changes in process operating procedures (for example, scheduling production in heat treating so that unneeded furnaces can be kept turned off), standard recommendations that needed to be re-emphasized, and research into promising new technologies.

3.2.1 *Energy and Environmental Data*

3.2.1.1 Energy Data. As described above, Robins has an extensive network of electric meters on individual buildings and some steam meters. These meters make it possible to collect data for energy consumption for a process area as a whole. Energy usage at the process level for the evaluation of ECOs must still be estimated using engineering judgment and data on equipment characteristics and specifications obtained from equipment manufacturers.

Table 19 lists the total annual usage of energy at RAFB for the last 3 fiscal years. The consumption of natural gas and fuel oil for the generation of steam for the past two, 12-month periods is shown in Table 20. Finally, energy usage for some individual process areas at WRALC is shown in Table 21.

3.2.1.1.1 C-130 Plane Depainting (Building 50). C-130 planes are depainted and painted in a large hangar. Depainting is carried out for the most part with high-pressure baking soda washing systems. As many as five workers at a time work on a plane. There are generally two shifts, 7 days per week. About 4 days are required for depainting a plane.

The hangar is air conditioned with its own two dedicated chillers. Air is recirculated when painting is not being done. When painting is being done, ventilating air is circulated on a once-through basis with the air passing downdraft through the floor and out through rooms filled with painting filters. If the temperature and the humidity are too high, the ventilating air is air conditioned on a once-through basis. Three different painting processes are conducted: (1) polysulfide priming of aircraft panels, (2) high-solids priming of the aircraft, and (3) polyurethane topcoating of the aircraft.

Table 19. Annual energy use at RAFB.

FY	Electricity MWh	Electricity MBtu	Gas MBtu	Water kgal	Sewage kgal	Fuel Oil MBtu	Industrial Waste kgal	Steam MBtu
FY93	241,699	824,919	895,489	971,428	479,454	22,993	140,396	902,074
FY94	252,360	861,305	978,401	1,054,474	603,428	26,449	128,101	995,640
FY95*	271,726	927,401	936,577	661,426	591,584	39,571	154,902	612,862**

* Total primary thermal energy consumed = 936,577 + 39,571 = 976,148 MBtu

** Significant decrease in steam usage probably caused by increased direct use of gas-fired heaters for heating.

Table 20. Consumption of fuel oil and natural gas for generation of steam at WRALC.

Mo/Yr	Natural Gas Mcf	Fuel Oil (#2) gal	Steam Generated* MBtu	Total Energy** MBtu	Steam Generation Efficiency %***
7/93	38	0	31,745	38,123	83.3
8/93	38	0	31,784	38,425	82.7
9/93	34	0	28,223	34,082	82.8
10/93	34	0	28,493	33,683	84.6
11/93	71	6,865	60,961	71,931	84.7
12/93	113	786	95,349	112,916	84.4
1/94	77	396,503	112,236	132,443	84.7
2/94	83	88,298	82,044	95,246	86.1
3/94	79	0	67,725	79,032	85.7
4/94	41	0	35,013	41,131	85.1
5/94	33	0	29,069	33,357	87.1
6/94	30	0	25,494	29,928	85.2
Total	**671**	**492,452.00**	**628,136**	**740,297**	**84.7**
7/94	31	0	26,737	31,376	85.2
8/94	28	0	23,233	28,338	82.0
9/94	30	0	26,509	30,466	87.0
10/94	30	0	26,048	29,504	88.3
11/94	42	0	36,622	42,236	86.7
12/94	84	0	71,677	84,059	85.3
1/95	100	83,667	95,726	111,613	85.8
2/95	73	158,191	81,523	94,879	85.9
3/95	70	5,529	61,027	70,966	86.0
4/95	34	1,188	29,349	34,119	86.0
5/95	28	0	24,751	28,025	88.3
6/95	26	169	22,480	26,496	84.8
Total	**576**	**248,744**	**525,682**	**612,077**	**85.9**

* Steam generated in steam plants in Buildings 177 (main power plant) and 644.
** Natural gas @ 1000 Btu/cf and fuel oil @ 0.140 MBtu/gal.
*** 100 x Steam MBtu/Total MBtu. (Numbers may be too high, should be around 70–74 percent as stated by base energy coordinator.)

Supposedly, the hangar must be climate controlled because temperature and humidity affect paint quality, but the main reason for air conditioning may be simply worker comfort. If air conditioning and climate control are not really needed for paint quality, the workers can perhaps be kept comfortable with suits cooled with a stream of compressed air (available on the market). If C-141s and F-15s can be painted in hangars without using air conditioning (see below), perhaps C-130s can be as well.

Table 21. Energy usage by process area at WRALC, 8/94-7/95.

Building	Process Area	Total Electricity MBtu	Total Steam MBtu	Steam for Process Use* MBtu	Steam for Heating Use** MBtu
50	Plane depainting/painting hangar	14,268	21,234	0	21,234
110	Depainting/painting hangar	3,865	27,294	0	27,294
125	General aircraft maintenance hangar	21,168	10,723	0	10,723
130	Main compressor building	13,022	na	na	na
140	Heat treat/foundry shop***	22,607	4,970	1,893	3,077
142	Electroplating shop	13,759	33,099	11,645	21,454
158	Gyro repair	13,850	20,182	0	20,182
180	Aircraft component depainting/painting	3,834	13,444	8,086	5,358
670	Radome repair	3,191	1,208†	606†	602†

* Monthly average for 6 months (i.e., ex. October-March) x 12.
** Total usage - process usage.
*** Also uses 709 MBtu of propane for the foundry.
† Natural gas.

***3.2.1.1.2* C-141 Plane Painting (Building 54)**. Building 54 is a hangar used for painting C-141 planes 7 days/week. The building is heated with steam whenever painting is being done, and infra-red heaters at other times. This building has no chiller for air conditioning. The process of painting a plane is to: (1) sand it, (2) mask off areas not to be painted, (3) wash with soap and water, (4) apply etch corrosion remover, (5) apply "Alodyne" corrosion protector, (6) apply primer, (7) paint with high-solids polyurethane paint, (8) apply second coat, and (9) apply stencils. HVLP guns are used. They are regarded as slow (a universal complaint). It takes five painters about 3 to 4 hours for one coat of paint, using 50 to 70 gal of paint. The hangar is equipped with filter walls that capture the paint particulates (filters changed twice a week). The hotter the hangar temperature is, the greater the amount of paint used.

***3.2.1.1.3* C-141 Plane Depainting (Building 110)**. The first operation done in depainting a C-141 is to apply a paint remover (1056, alcohol-based, considered nonhazardous—about 8 drums) to soften the paint, which takes about 24 hours. Fiberglass areas are then taped up. Depainting is done with high-pressure baking soda washing systems. As many as eight or nine workers at a time work on a plane. There are generally three shifts, 7 days per week. About 4 days are required to depaint a plane (1 for prep, 2 for "shooting," and 1 for clean-up). Paint particles are

washed down into a pit below the floor. The wastewater is filtered, and waste is hauled off as hazardous waste. After the depainting, the plane is washed with soap and water.

Each high-pressure baking soda washing machine costs from $36,000 for a base machine up to $63,000 for a customized one. Each gun costs $2,600. Each gun tip costs $90 and lasts 20 hours of operating time.

In this building, there is no forced ventilation; the building is heated with central steam.

3.2.1.1.4 **Main Compressor Plant (Building 130).** The main compressor plant consists of two, 450-hp compressors (each produces 2000 cfm at 110 psi), and one 350-hp (1500 cfm) compressor, all screw-type single-stage lubricated compressors. There are three air dryers. If there is no demand for 28 minutes, the compressors automatically shut off. There are other compressors on the base (Building 51—two 450-hp and one 300-hp piston-type compressors; Building 83—two 350-hp piston-type compressors).

3.2.1.1.5 **F-15 Plane Depainting and Painting (Building 137).** F-15s are depainted using plastic blasting media. Blasting with frozen CO_2 particles was tried on F-15s, but was found to be too slow at the pressure needed to avoid damaging the skin of the plane. The amount of compressed air used is 2300 cfm at a blasting pressure of 28 psi (throttled from the 100 psi of the central supply).

A paint bay using robotics was set up for F-15s, but is not used at present. Painting done manually is done at night and in the morning when the ambient temperature is not as hot. Painting F-15s is usually done with two workers, each gun consuming 10 to 12 cfm at 30 psi.

If the work on F-15s can be done with compressed air at no more than 30 psi pressure, perhaps it would pay to install a separate small portable compressor or blower in this building (which is isolated from the other, larger hangars) to avoid the losses caused by throttling the 100-psi central supply, and the leaks in the line out to this building.

3.2.1.1.6 **Heat Treating Shop (Building 140).** The heat treating shop has some 16 furnaces, about half of which are used to treat ferrous metal parts (@1600 to 2000 °F) and half for aluminum parts (@800 to 1000 °F). All of the furnaces are electric since gas was not available to the area when the shop was installed. Most of the furnaces are small and used infrequently. However, there are a couple of furnaces

with firebrick construction that are kept on all the time, although they are turned down to 1200 °F on weekends and 1600 °F overnight after the second shift.

The largest, most important furnace for treating ferrous parts is an integral quench furnace which has an endothermic atmosphere (neutral with respect to any change in the carbon content of the part) created by burning propane over a Ni catalyst. The maximum heating load is 145 kW (other uses of electricity account for an additional 36.5 kW; there is consumption also of propane and 22.2 cfm of compressed air).

One vapor degreaser uses trichloroethane, but is to be replaced with a power washer.

The largest furnace is a drop bottom solution heat treating furnace equipped with a quench system (20 percent solution of glycol in water) for treating large aluminum parts. The maximum heating load is 432 kW.

Aside from the usual energy conservation opportunity of installing better, more up-to-date controls and instrumentation on the electric furnaces, there would not appear to be any significant opportunities on the furnaces themselves. (Replacing them with gas-fired furnaces if that opportunity were to arise would probably save some operating cost.)

However, significant amounts of electrical energy could be saved by not turning the furnaces on unless needed, i.e., anticipatory production scheduling is needed. Typically, many of the furnaces are turned on in the morning to heat up to be ready for any potential production that comes through the door, but the production logs show that the furnaces sit idle, heated to process temperature, a good bit of the time. At least the big furnaces should be given long weekends off unless production capacity is needed, as scheduled.

Every morning (particularly on Monday morning), there is a significant spike in electrical demand as the furnaces are heating up. There is also a spike at the end of the second shift when presumably the furnaces are being turned off or down. The EnerLink plots of electrical demand should be analyzed by the operations people to determine the causes of these surges in electricity consumption and possibly figure out a way to dampen them.

3.2.1.1.7 **Foundry (Building 140)**. The foundry contains three melting pots currently fired with propane. These pots are used mainly to melt lead (at 800 °F) and aluminum (at 850 °F). They were installed at a time when natural gas was not available to this area. Since gas is now not far away from this building, gas should be piped in and used for these melting pots because it is cheaper than propane. The

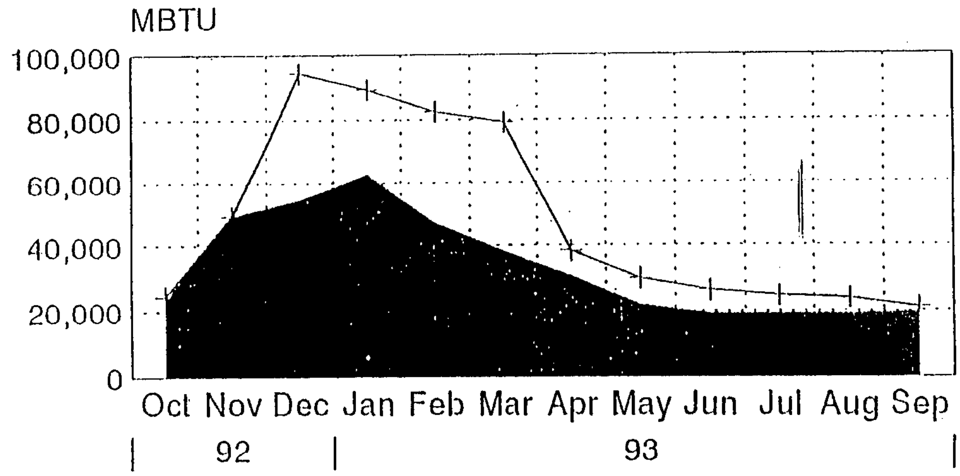
pots exhaust into the work space. An exhaust fan for the foundry area is used in the summertime.

3.2.1.1.8 **Plating Shop (Building 142)**. Several operations are conducted in this shop: (1) dry media blasting, (2) ion vapor deposition, (3) oven drying, and (4) plating. Steam is used to heat individual plating tanks when they are needed. The tanks that are heated have integral insulation in their walls. Ventilation air is supplied to the plating area with two, 125-hp fans. Some 15 exhaust fans (same total hp) exhaust the air. The plating operations are vented to 12 stacks, of which two have control devices (scrubbers/demisters). Most chromium emissions are vented to these stacks. Rectifiers are used to supply the DC power to the tanks. Countercurrent rinsing is not used because, when the shop was redesigned a few years ago, this concept was not yet widely known and developed. Consequently, it was not considered.

3.2.1.1.9 **Central Steam and Chilled-Water Plant (Building 177)**. The central plant responsible for generating most of the steam used in process areas has two, 100,000-lb/hr boilers and three, 55,000-lb/hr boilers. Natural gas (interruptible) is used with oil backup. The 100,000-lb/hr boilers and one 55,000-lb/hr boiler are used in the wintertime; one 55,000-lb/hr boiler is used in the summertime. Two 1500-ton and one 750-ton centrifugal chillers are used; a 1000-ton absorption chiller is to be replaced with another 1500-ton centrifugal unit. Four new cooling towers (one for each chiller) are to replace six old ones. Steam is generated at 125 psia.

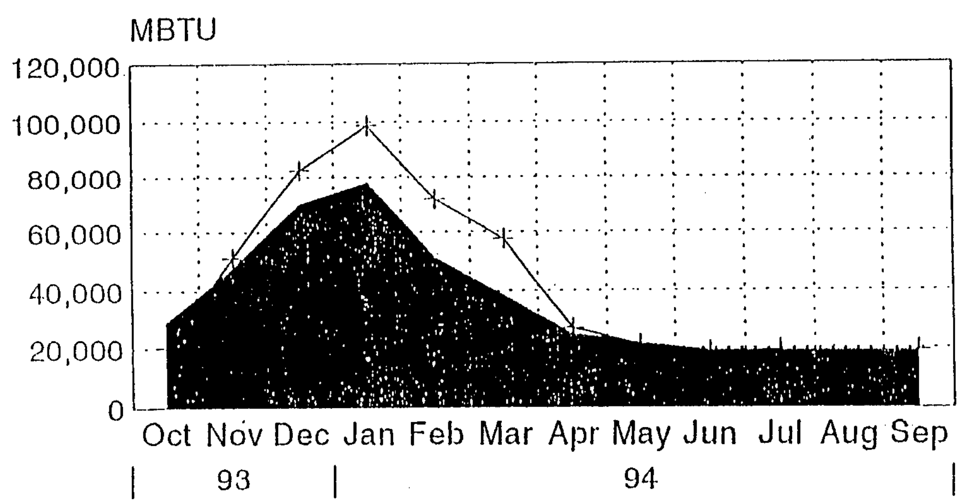
In the summertime, steam lines into individual buildings are cut off, but blocking main steam lines off is considered to lead to maintenance problems. Lowering the steam pressure is not seen as an option; the pressure is thought to be needed to push the steam through the 75 miles of lines, and the higher pressure provides a pressure cushion if a boiler goes down. This pressure cushion is thought to be needed to prevent lines from getting cold and filling up with water.

Steam is needed in the summertime for processes considered critical: plating and depainting. In the wintertime, a great deal of steam has been wasted with the boilers producing flat out at the maximum capacity because the hangar doors in hangars used for airplane repair are typically left wide open (for workers' convenience in moving planes, parts, and tools in and out). Some progress is being made to stop this practice. (Compare Figures 1 and 2. The savings in the "excess" energy consumption—91,287 MBtu from October to May—is attributed to this one conservation practice.) It has been found economical to convert the space heating in warehouses and some administration areas to gas-fired infra-red heaters (with propane backup). Interruptible gas is priced at $2.10/MBtu (firm gas at $4.50/MBtu).



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
%Diff	-4	0	-73	-42	-76	-106	-24	-37	-37	-28	-25	-7
Goal ■	23,710	49,232	54,707	63,045	46,957	38,450	31,122	22,025	19,330	19,330	19,330	19,751
Actual -|-	24,648	49,109	94,598	89,453	82,617	79,310	38,452	30,211	26,521	24,836	24,092	21,202
HDD	52	355	420	519	328	227	140	32	0	0	0	5

Figure 1. Steam production plant (B177)—October 1992 to September 1993.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Goal ■	28,862	48,096	70,165	78,065	51,360	38,479	24,826	21,906	19,330	19,330	19,330	19,330
Actual -|-	20,221	51,234	82,446	98,673	71,761	57,540	26,831	20,916	18,620	19,328	16,132	19,256
HDD	111	335	592	684	373	223	64	30	0	0	0	0

Figure 2. Steam production plant (B177)—October 1993 to September 1994.

The operating (O&M) cost of steam is thought to be $1.00-1.50/MBtu. Progress is being made in getting the steam distribution lines (all underground) in good shape (steam trap maintenance, etc.).

***3.2.1.1.10* Depainting and Painting (Parts) Shop (Building 180)**. The depainting area includes chemical stripping, conversion coating, and washing. The depainting equipment consists of a series of tanks and a spray booth. The tanks include alkaline and acid cleaning tanks, water rinse tanks, and conversion coating tanks. The parts are depainted with paint remover, such as methylene chloride, which is washed into the industrial wastewater system. The part is then washed with soap and water, and subjected to a variety of treatments for corrosion control, depending on the part and the kind of material. Some of these treatment tanks are kept hot with steam. To decrease the amount of paint remover used, a high-pressure water system is now being used on some parts. This system generates a water jet at 15,000-psi pressure that is mixed with baking soda and used for depainting. Some steam cleaning is still needed.

In the painting shop, there are four medium-size paint booths, each open at the front and equipped with a water wash system at the back for particulate control. These booths are used to paint aircraft parts, primarily with the following paints: (1) epoxy primer, (2) polyester primer, and (3) polyurethane topcoat. To clean the paint sludge from the washwater, there is a Sanborn cleaner, essentially a centrifuge that separates the sludge from the water and ejects the sludge into a drum via compressed air. Each booth is equipped with a 25-hp fan to circulate air through the booth and the water curtain. There were a large number of parts in the shop on carts drying under ambient conditions, which may account for the significant concentration of VOCs in the shop atmosphere. HVLP spray guns were used with high-solids paint.

***3.2.1.1.11* Radome Repair (Building 670)**. This building is air conditioned because of a required environment for the fiberglass radomes. The radomes are first depainted (washed with methylethyl ketone (MEK) and then C4411 epoxy stripper), followed with a hand wipe with MEK. The remaining paint is sanded off with a vacuum sander; the sanding dust and paint are collected as a hazardous waste. A resin seal coat is then applied to smooth the surface, and the resin is cured by heating the radome in an electric oven for 2 hours at 160 °F. There are two such ovens.

Damaged areas are then repaired with fiberglass resin and cloth. The repaired areas are sanded, then sealed with the resin (which requires more curing in the oven). The radomes are tested for radar transmission characteristics before (in

the C-130 and C-141) or after (in the F-15) being painted. The radomes are painted in a paint booth with a water wash system, which is cleaned once a week by a contractor. HVLP guns are used. The painter was asked whether she noticed using less paint with the HVLP guns compared with conventional guns. With the greater transfer efficiency of the HVLP guns, less paint should be needed and used to cover the same area, but the painter did not seem to notice much difference in the amount of paint used. Maybe the coat of paint was thicker, a factor that may not be desirable. Painting specifications may be needed to control the amount of paint used per coat with HVLP guns, with subsequent savings in the amount of paint used. After being painted, the F-15 radomes go back to the oven for 4 hours.

The building is heated with natural gas-fired boilers. There is a compressed-air system (single-stage screw compressor), and a vacuum system (15 hp). A recent energy conservation measure was to install an automatic shut-off for the vacuum system at night (after the patches on radomes, which require a vacuum, are finished curing).

The installation date of the ovens is not certain; they might be 15 years old. With natural gas now being available to the building, natural-gas, or infra-red ovens should perhaps be considered as replacements.

***3.2.1.1.12* Other Buildings and Miscellaneous**. The industrial wastewater treatment plant (two plants—one for plating wastes and the other for washdown water) and an environmentally controlled building for electrical equipment and gyro repair (requirements for humidity control; a "Class 100,000 clean room") were also surveyed.

3.2.1.2 Environmental Data. An extensive discussion was held with people in the Environmental Management Division about pollution sources at RAFB, data on emissions, and recycling—e.g., recycling of solvents via recovery stills. RAFB has five recovery stills, heated by steam, for recovering Freon, trichloroethane, isopropyl alcohol, MEK, and PD680 paint thinner.

Environmental data for WRALC were available from a contractor's report (Day and Zimmerman, and SAIC May 1993), which reported on the development of an emissions inventory for the facility. This report describes the effort to quantify actual emissions from particular processes. The analysis in this report included 27 buildings believed to have the greatest potential to emit HAPs. These buildings and their processes are listed in Table 22. Some comments on the environmental characteristics of these buildings and processes follow.

Table 22. Summary of building processes included in emissions inventory for WRALC.

Building No.*	Painting: Plane Hangar	Painting: Paint Booths	Painting: Outdoor, Uncontrolled Painting	Chemical Depainting	Corrosion Control	Electroplating/ Anodizing	Cleaning/ Degreasing/ Thinning	Sealants and Adhesives
40							×	×
44			×				×	×
47			×				×	×
49			×				×	×
50	×			×	×		×	
54	×			×	×		×	×
55							×	
89	×						×	×
91							×	×
110							×	×
125			×				×	×
131							×	×
137	×				×		×	×
140		×					×	×
142						×	×	
149			×				×	×
158		×					×	
169		×				×	×	×
180		×		×	×		×	
310							×	×
603								×
640		×				×	×	
645		×					×	
670/680**		×		×			×	×
H1***							×	×
H2							×	×
Pad 9			×					

* In addition to buildings listed above, the following processes are also included in this emission inventory: fuel storage and transfer, boilers, and incinerators.

** Buildings 670 and 680 are considered together because materials for Building 680 are purchased through Building 670.

*** H1 and H2 are newly built repair hangars on the flightline.

***3.2.1.2.1* Paint Hangars**. Painting of aircraft is conducted in several hangars. Paints used include primers, polyurethane topcoats, lacquers, and enamels. Primers used include polyurethane (high-solids) primers, polyamide epoxy primers, polysulfide primers, polyester primers, and zinc chromate primers. Each hangar has its own pollution control and ventilation system. Building 50 has a vertical ventilation system in which air is drawn from the roof, exits through grates in the floor, and flows beneath the floor up through large banks of fabric filters at the end of the building into two stacks.

Building 54 has a lateral ventilation system in which air enters the hangar through the front doors and exhausts through banks of fabric filters at the back of the hangar. Emissions from the painting operations include VOCs, semivolatiles, and inorganic compounds.

***3.2.1.2.2* Paint Booths**. Painting of parts is conducted in a number of paint booths. Many of these booths are equipped with fabric filters to control particulate emissions. A few other booths have water curtains. The major types of paints used in the booths are epoxy primers, polyester primers, polyurethane coatings, enamels, and lacquers.

***3.2.1.2.3* Chemical Stripping/Depainting**. Chemical stripping/depainting of aircraft and parts are conducted in large hangars and in booths. Two types of stripping agents are used. Methylene chloride-based strippers are the most widely used on base. A benzyl alcohol-based stripper, which does not contain any HAP compounds, is also used.

***3.2.1.2.4* Corrosion Control**. Corrosion control compounds are applied to aircraft and parts after stripping and cleaning, before repainting. Corrosion control consists of two operations usually conducted in series: (1) corrosion removal and (2) chromate conversion coating. Corrosion removal refers to the application of a brightener to the metal surface of the part. The brightener typically contains concentrated hydrogen fluoride (HF) and may be applied by tank immersion or spraying. Corrosion removal also refers to the removal of smut and paint particles, and the general cleaning of metal surfaces. The process can include the following chemicals: glycol ethers, sodium hydroxide, trisodium phosphate, and degreasing agents such as 1,1,1-trichloroethane.

Chromate conversion coating treatments convert the surface layer of metal into a complex film of chromium compounds. The chromate conversion coatings contain hexavalent chromium and sometimes cyanides. The coatings may be applied by immersion, spraying, or brushing.

***3.2.1.2.5* Electroplating and Anodizing**. In electroplating and anodizing operations, a metal piece is submerged in an electroplating bath, and a metal coating is applied. Emissions of organic HAPs occur as a result of volatilization from the plating solutions. Emissions of inorganic and semivolatile HAPs result from entrainment in the agitated tanks and from "dragout" when the piece is removed from the tank. Electroplating processes in Building 142 include alkali cleaning, acid rinses, conversion coating, anodize stripping, sulfuric acid anodizing, dichromate sealing, vapor degreasing, titanium etching, deoxidizing, masking, chromic anodizing, chrome plating, magnesium coating, waxing, and rinsing. Chemicals used in electroplating that are considered HAPs include hydrochloric acid, hydrofluoric acid, chromic acid, sodium dichromate, sodium cyanide, and manganese.

***3.2.1.2.6* Summary**. Tables 23 (VOC emission rates), 24 (semivolatile organic emission rates), and 25 (metals, acids, and cyanide emission rates) summarize the annual HAP emissions for each building and process included in RAFB's air emissions inventory.

3.2.2 Analysis of Data

3.2.2.1 Energy Data. The data in Table 19 on total energy use at Robins shows that the major energy cost is associated with the purchase and use of electricity. On the basis of energy content, however, thermal uses of energy account for about half of the energy use at Robins, 51.3 percent in FY95 versus 48.7 percent for electricity. Thermal energy is provided almost exclusively by using gas at Robins.

The data in Table 20 on monthly production of steam were analyzed to estimate the proportion of steam used for heating and nonheating (i.e., process) uses. Based on the amount of steam used monthly during the nonheating season and assumed to represent an essentially constant process load, it is estimated that approximately 57.0 percent of the steam generated at Robins is used for process uses (see Table 26), which includes the energy required to run the steam system.

The energy data in Table 21 indicate the total amounts of energy used at RAFB for the various processes surveyed on the site visit. The total amount of steam for each building was analyzed to estimate the amount used for process use and that used for heating. The major process uses of steam appear to be heating vats in the electroplating shop and steam cleaning aircraft components before painting them.

Table 23. Summary of emission inventory results—volatile organic compounds.

Building	Emission Rate (lb/yr) Acet-aldehyde	Benzene	Ethyl Benzene	Formal-dehyde	Hexane	Methanol	MEK[a]	MIBK[b]	Methylene Chloride	Toluene	1,1,1-TCA[c]	Xylenes
40	—	—	—	—	—	—	100	—	—	89	210	—
44	—	—	—	—	—	—	90	—	6.3	220	—	—
47	—	—	—	—	—	—	81	—	63	410	150	—
49	—	—	0.61	—	—	—	360	51	380	980	58	62
50	—	—	100	—	—	—	2,000	8,800	560,000	2,700	—	200
54	—	—	—	—	—	—	12,000	—	515,000	210	—	—
55	—	—	—	—	—	—	3.5	—	—	3.5	—	—
89	—	—	120	—	—	—	20,000	10,000	710	7,600	1.5	800
91	—	—	—	—	—	—	830	—	—	890	1,100	—
110	—	—	—	—	—	—	88	—	—	87	61	—
125	—	—	1.1	—	—	—	640	86	42	810	4,300	1.4
131	—	—	—	—	—	—	—	—	—	—	30	—
137	—	—	1.2	—	—	—	10,000	42	0.46	5,300	830	290
140	—	—	0.80	—	—	—	12,000	67	17	150	2,300	34
142	—	—	—	—	—	—	—	—	5,000	8,800	110,000	—
149	—	—	—	—	—	—	—	—	—	36	40	15
158	—	—	—	—	—	—	—	—	—	57	2,400	38
169	—	—	—	—	—	—	36	—	—	59	8,800	—
180	—	—	57	—	—	120	12,000	1,500	114,000	12,000	—	1,000
310	—	—	—	—	—	—	2.4	—	—	5.7	4,700	—
603	—	—	—	—	—	—	17	—	—	34	—	—
640	—	—	—	—	—	—	180	—	1,100	350	2,300	110
645	—	—	—	—	—	—	48	—	8.0	310	3,100	180
670/680	—	—	21	—	—	120	4,200	1,800	1,500	460	100	66
H1	—	—	—	—	—	—	100	—	—	18	47	—
H2	—	—	—	—	—	—	2.1	—	—	3.0	—	—
Pad 9	—	—	55	—	—	—	300	740	—	360	—	200
Boilers	23	14	—	27	—	—	—	—	—	5.8	—	2.1
Fuel Usage	—	160	—	—	400	—	—	—	—	130	—	—
Medical Incinerator	—	0.011	<0.01	—	—	—	—	—	—	0.010	—	0.018
Classified Incinerator	6.8	32	—	27	—	—	—	—	—	7.9	—	—
Total	**30**	**210**	**360**	**54**	**400**	**240**	**75,000**	**23,000**	**1,200,000**	**42,000**	**140,000**	**3,000**

* Methyl ethyl ketone.
** Methyl isobutyl ketone.
*** 1,1,1-trichloroethane.

Table 24. Summary of emission inventory results — semivolatile organic compounds.

Building No.	Emission Rate (lb/yr)								
	Acrolein	1,3 - Butadiene	Chlorobenzene	Cresol	Diethanolamine	DMF*	EGBE**	Epoxy Resin***	Naphtha
40	—	—	—	—	—	—	—	0.41	130
44	—	—	—	—	—	—	—	67	30
47	—	—	—	—	—	—	—	61	26
49	—	—	—	—	—	0.53	—	13	460
50	—	—	—	—	—	280	6.7	160	—
54	—	—	—	—	—	—	—	3.5	—
55	—	—	—	—	—	—	—	—	5
89	—	—	—	—	—	400	2.6	220	4
91	—	—	—	—	62	—	180	36	1,100
110	—	—	—	—	—	—	—	7.2	86
125	—	—	—	—	5.6	2.2	17	30	800
131	—	—	—	—	—	—	—	—	—
137	—	—	—	—	—	—	1.1	—	—
140	—	—	—	—	—	1.3	—	9.0	—
142	—	—	—	—	44	—	130	—	—
149	—	—	—	—	—	—	—	—	—
169	—	—	—	—	44	7.8	130	12	—
180	—	—	—	13,000	—	70	730	39	—
310	—	—	—	—	—	—	—	2.4	—
603	—	—	—	—	—	—	—	17	—
640	—	—	—	—	—	—	<0.85	—	—
645	—	—	—	—	—	—	—	5.5	—
670/680	—	—	—	—	—	—	—	1.3	—
H1	—	—	—	—	—	—	—	—	9
H2	—	—	—	—	—	—	—	—	3
Pad 9	—	—	—	—	—	—	74	—	—
Boilers	10	6.6	0.18	—	—	—	—	—	—
Medical Incinerator	—	—	—	—	—	—	—	—	—
Classified Incinerator	—	—	—	—	—	—	—	—	—
Total	**10**	**6.6**	**0.18**	**13,000**	**160**	**760**	**1,300**	**680**	**2,700**

	Naphthalene	Phenol	Phenolic Resin†	PAHs††	POM†††	PGMEA‡	PGME‡‡	2,2,4-Trimethylpentane	
40	—	—	0.76	—	—	—	—	—	
44	—	—	67	—	—	—	0.6	—	
47	—	—	61	—	—	—	6.0	—	
49	—	—	13	—	—	—	36	—	
50	—	52,000	—	—	—	—	26	—	
54	—	—	220	—	—	—	—	—	

	Naph-thalene	Phenol	Phenolic Resin†	PAHs††	POM†††	PGMEA‡	PGME‡‡	2,2,4-Trimethyl-pentane	
55	—	—	36	—	—	—	—	—	
89	—	—	8.7	—	—	—	74	—	
91	—	—	40	—	—	—	—	—	
110	—	—	3.2	—	—	—	—	—	
125	—	—	3.7	—	—	—	4.4	—	
131	—	—	57	—	—	—	—	—	
137	—	—	—	—	—	—	2.6	—	
140	—	—	0.37	—	—	—	1.6	—	
142	—	—	26	—	—	—	—	—	
149	—	—	39	—	—	—	—	—	
169	—	—	5	—	—	—	—	—	
180	—	4,700	17	—	—	100	120	—	
310	—	—	—	—	—	—	—	—	
603	—	—	5.5	—	—	—	—	—	
645	—	—	1.4	—	—	—	0.76	—	
670/680	—	—	—	—	—	—	—	—	
H1	—	—	—	—	—	—	—	—	
H2	—	—	—	—	—	—	—	—	
Pad 9	—	—	—	—	—	—	170	—	
Boilers	160	—	—	180	—	—	—	—	
Fuel Usage	—	—	—	—	—	—	—	670	
Medical Incin-erator	0.25	—	—	—	—	—	—	—	
Classified Incinerator	—	—	—	—	9.9	—	—	—	
Total	**160**	**57,000**	**600**	**180**	**9.9**	**100**	**440**	**670**	

*Dimethylformamide.

**Ethylene glycol monobutyl ether (synonyms are butyl cellosolve and 2-butoxyethanol).

***4,4-Isopylidene phenol epichlorohydrin polymer.

†Phenol polymer with formaldehyde.

††Polycyclic aromatic hydrocarbon.

†††Polycyclic organic matter.

‡Propylene glycol monomethyl ether acetate.

‡‡Propylene glycol monomethyl ether.

Table 25. Summary of emission inventory results — metals, acids, and cyanides

Building	Emission Rate (lb/yr)											
	Arsenic	Beryllium	Cadmium	Chromium (Total)	Cyanide	Hydro-chloric Acid	Hydro-fluoric Acid	Lead	Manganese	Mercury	Nickel	Selenium
344	—	—	—	0.21	—	—	—	—	—	—	—	—
47	—	—	—	2.1	—	—	—	—	—	—	—	—
49	—	—	—	13	—	—	—	—	—	—	—	—
50	—	—	—	67	<0.06	—	—	—	—	—	—	—
54	—	—	—	6.0	<0.6	—	340	—	—	—	—	—
89	—	—	—	0.39	—	—	—	—	—	—	—	—
125	—	—	—	1.9	—	—	—	—	—	—	—	—
137	—	—	—	2.1	<0.12	—	28	—	—	—	—	—
140	—	—	—	0.31	—	—	—	—	—	—	—	—
142	—	—	6.4	13	190	1.9	1.3	—	8.7	—	—	—
169	—	—	0.17	<2.0	—	—	—	—	—	—	—	—
180	—	—	—	67	—	—	856	—	—	—	—	—
640	—	—	—	—	<0.4	22	—	—	—	—	—	—
645	—	—	—	0.049	—	—	—	—	—	—	—	—
670/680	—	—	—	29	—	—	—	—	—	—	—	—
Pad 9	—	—	—	23	—	—	—	—	—	—	—	—
Boilers	0.58	0.58	0.98	0.14	—	160	—	5.7	1.4	0.13	3.2	0.35
Medical Incinerator	<0.01	—	0.026	—	—	2.6	—	0.31	<0.01	0.41	—	—
Total	**0.58**	**0.58**	**7.6**	**230**	**190**	**190**	**1,200**	**6.0**	**10**	**0.54**	**3.2**	**0.35**

Table 26. Analysis of steam usage at Robins Air Force Base.

Season	No. of Months	Total Steam (MBtu)	Percent of Total Steam	Monthly Average (MBtu/mo.)
Heating	6	375,924	71.5	62,654 (6 mo.)
Non-heating	6	149,758	28.5	24,960 (6 mo.)
Totals	12	525,682	100.0	43,807 (12 mo.)
Process use = 24,960 MBtu/mo x 12 mo = 299,520 MBtu/yr (57.0% of total annual steam) Heating use = 525,682 MBtu/yr - 299,520 MBtu/yr = 226,162 MBtu/yr (43.0% of total annual steam)				

3.2.2.2 Environmental Data. The data collected for this inventory and the subsequent engineering evaluation led to the following conclusions:

- The major HAP-emitting source at WRALC is chemical depainting, with an estimated annual emission of approximately 1.2 million lb of methylene chloride.
- Several VOCs are emitted at annual rates between 40,000 to 150,000 lb: 1,1,1-trichloroethane, methyl ethyl ketone, phenol, and toluene.
- Due to the high toxicity of hexavalent chromium, the annual chromium emissions of 230 pounds, primarily from chromate conversion coating operations, are considered significant.
- Chromium emissions from chromate conversion coating operations appear to be reduced substantially by the presence of metal filters.
- Emissions of HF (1200 lb/yr), primarily from the corrosion control brightener/etchant application, are considered significant.
- Potential emissions of HDI (hexamethylene-1,6-diisocyanate) from controlled painting operations need further evaluation.
- The incinerators, boilers, and fuel transfer operations are minor contributors to base-wide HAP emissions.

Recommendations related to process changes were:

- Continue depainting research to find a suitable replacement for methylene chloride-based depainting and hexavalent chromium-based corrosion control.
- Implement pollution prevention strategies at all major HAP emission sources, particularly at painting, depainting, electroplating, and general solvent usage areas.
- Implement control of chromium emissions in depainting operations.
- Implement VOC control at major painting and depainting sources.
- Reduce HF emissions at corrosion control sites.

3.2.2.3 Facility Conditions. Another objective of making the site visits was to examine facility conditions. The general impression from observation of the physical condition of the processes at WRALC was that they have been well maintained. Most of the process equipment observed is only a few years old. The central air compressors are quite new; they are, however, single-stage compressors, which are less efficient. The chillers in the central plant are being upgraded with a new centrifugal chiller to replace an old absorption chiller, and new cooling towers are also being added.

3.2.3 PEPR Opportunities with Estimations of Investment and Savings

As the result of observing the process operations at Robins and collecting process data, a number of ideas for conserving energy in the process operations were conceived. The ECOs identified for Robins for those process areas visited during the site visit and analyzed are listed in Table 27. A number of these ECOs are similar to ECOs listed for Anniston Army Depot. The results of the analyses are also shown in the table. Some other process ECOs evaluated in a previous study (Day and Zimmerman, and SAIC 7 September 1990) are also included so that they could be recommended to other Air Force bases. ECOs for which insufficient information was available for their analysis are listed in Table 28.

3.2.4 Prioritized List of Recommendations for Air Force Bases to Implement

Table 29 is a prioritized list of the ECOs evaluated for Air Force bases, based on Robins; Table 29a is prioritized with respect to annual energy savings and 29b with respect to payback period.

In this table for Air Force bases, savings that could be achieved by overhauling the central steam distribution system (finding and fixing leaks and traps, etc.) are not included, but their potential is, or should be, well recognized for their payback and energy savings. The ECOs for Anniston for the steam distribution system indicate that this area has significant potential savings. The potential savings at Robins for the steam system may be even more than at Anniston because the system at Robins has over three times the length of lines.

The sum total of listed process ECOs to save thermal energy at Robins Air Force Base is 138,737 MBtu/yr, to be compared to a total of 976,148 MBtu of thermal energy consumed annually by the base (see Table 19, p 63)—about 14 percent. The sum total of process ECOs saving electricity is 19,547 MBtu/yr, to be compared to a total of 927,401 MBtu of electricity consumed annually by Robins Air Force Base—

Table 27. Summary and evaluation of process ECOs at Robins Air Force Base.

Description of ECO	Capital Cost $	O&M Saving $/yr	Energy Saving MBtu/yr	Payback yr	Return on Investment %	Savings-to-Investment Ratio (SIR)	Classification and Remarks
Electroplating Shop (Building 142)							
Replace air agitation with electric agitators in tanks.	140,000	na	3,128[1] 4,320[2]	2.2	14.6	7.0	Technology replacement
Eliminate the use of steam for heating plating tanks (for example, install small natural gas burner system on each tank requiring heating).	155,000	na	-1,497[1] 10,738[2]	4.4	12.4	4.7	Process design modification
Reduce 100% overplating (to compensate for grinding) to 40-60%.	na	na	466[1] 689[2]	—	—	—	Operational modification
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss.	2,500	na	5,568[1] 10,630[2]	0.1	77.7	212	Operational modification
Heat Treating Shop (Building 140)							
Work load does not justify keeping both furnaces with endothermic atmosphere (nos. 6 and 8) turned on. Consider scheduling production so that no. 8's workload at 1600°F is done in no. 6 in the morning when it is at this temperature before it is heated up to 2000°F. Keep no. 8 turned off (not just down).	0	na	500	—	—	—	Operational modification
Consider leaving furnace 6 turned down on weekend schedule for two extra days per week to save energy; workload does not require this furnace to be turned up five days/week.	0	na	100	—	—	—	Operational modification
Change fuel used in foundry furnaces from propane to gas.	0	na	0 (cost saving)	—	—	—	Fuel substitution

Description of ECO	Capital Cost $	O&M Saving $/yr	Energy Saving MBtu/yr	Payback yr	Return on Investment %	Savings-to-Investment Ratio (SIR)	Classification and Remarks
Depainting (Parts) Shop (Building 180)							
Eliminate the use of steam for heating treatment tanks (for example, install small natural gas burner system on each tank requiring heating). (4 tanks)	20,000	na	-193[1] 1,390[2]	4.4	12.4	4,7	Process design modification
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss. (4 tanks)	350	na	720[1] 1,400[2]	0.1	77.7	212	Operational modification
Spray Paint Booths (Building 180)							
Evaluate a possible reduction in allowable ventilation rate for paint booths with the use of HVLP spray guns (less overspray and emissions). (4 booths)	0	na	4 x 624[1] 4 x 1,387[2] (5,550[2])	—	—	—	Operational modification
Install automatic dampers to close exhaust ducts when fans are de-energized. (4 booths)	4 x 1,700 (6,800)	na	4 x 150[1] 4 x 200[2] (800[2])	1.9	17.3	11.1	Control technology addition
Convert water wash booths to dry filter for particulate control. (4 booths)	4 x 1,670 (6,680)	4 x 5,000 (20,000)	4 x 240 (960)	0.2	28.6	70.2	Technology replacement
Building 670—Radome Repair							
Convert water wash booth to dry filter for particulate control.	1,670	5,000	240	0.2	28.6	70.2	Technology replacement
Install automatic dampers to close exhaust ducts when fans are de-energized.	1,700	na	150[1] 200[2]	1.9	17.3	11.1	Control technology addition
Miscellaneous							
Replace old standard-efficiency motors with energy-efficient ones, with a VFD if justified, in shop buildings [7].	503,578		12,738	5.6		1.97	Technology replacement
Keep doors of aircraft-repair hangars closed as much as possible in the heating season.	0	na	91,300	—	—	—	Operational modification

Description of ECO	Capital Cost $	O&M Saving $/yr	Energy Saving MBtu/yr	Payback yr	Return on Investment %	Savings-to-Investment Ratio (SIR)	Classification and Remarks
Replace conventional-source heaters in hangars and high-bay shop buildings with gas-fired infra-red heaters [7]. (17 hangars and 22 shop buildings)	343,315	na	16,729	5.0		2.14	Technology replacement

[1]Energy saved at the process.
[2]Energy saved in primary fuel, considering losses in central steam and compressed-air supply systems, and efficiency of steam generation.

Table 28. Summary of additional potential process ECOs at Robins Air Force Base.

Description of ECO	Classification and Remarks
Electroplating Shop (Building 142)	
Consider using a small portable air compressor, with VFD, or blower in the shop to supply air for cleaning (i.e., blowing dust and dirt) and drying parts (100-psi air is not needed).	Process design modification
Consider installing countercurrent rinsing systems.	Technology replacement
Optimize batch size (or use small tanks for small batches).	Operational modification
Install plating waste concentrators to recover and recycle plating solutions.	Technology replacement
Supply gas to the power washer for heat instead of electricity or steam.	Fuel substitution
Install VFDs on exhaust fans.	Process design modification
Heat Treating Shop (Building 140)	
Convert electric annealing/heat treating furnaces to natural gas where feasible.	Fuel substitution
Schedule production so that furnaces which are heated are used for two or more batches in succession to reduce heat-up/cool-down cycles.	Operational modification
Depainting (Parts) Shop (Building 180)	
Consider the use of blasting with frozen CO_2 particles for cleaning and depainting (particularly for parts which have been treated first with paint remover).	Technology replacement

Description of ECO	Classification and Remarks
Apply paint remover (methylene chloride) to parts over a special pit to catch the solvent for recycling, etc. rather than wash it into the industrial wastewater system.	Operational modification
Find substitute paint stripper for methylene chloride which emits fewer VOCs.	Technology replacement
Spray Paint Booths (Building 180)	
Evaluate the use of alternate, less hazardous (lower VOC content) paints.	Technology replacement
Train the painters in proper use of high-solids-content paint to avoid using more paint than is necessary.	Operational modification
Central Steam Supply System	
Optimize boiler pressure at lower levels using point-of-use pressure control with summer setback (0.1-0.2% savings/10 psi drop). (There appears to be no legitimate process need for 125-psi steam in the entire base).	Control technology addition
Defer proposed project to link two steam systems together for more efficient summertime boiler loads.	Operational modification
Decommission and/or idle selected segments of the steam system where piping runs in parallel or users are fed from two directions.	Operational modification
Central Compressed Air Supply System	
Optimize pressure of compressed air at lower levels using point-of-use pressure control (1% savings/2 psig drop).	Control technology addition
Survey actual process requirements -- air pressure and consumption -- for compressed air usages to identify all areas which could perhaps be satisfied with lower-pressure air, such as paint shops, plating shop, some uses in blasting booths, etc. It might pay to set up a separate low-pressure compressed-air circuit for those areas requiring only low pressure and dedicate some of the central compressors to low-pressure service.	Process design modification
Switch hand tools from pneumatic to electric (battery or cord) where possible.	Technology replacement
Locate, measure, and fix leaks in the central system.	Operational modification
Miscellaneous	
Consider installing an "air curtain" on large hangar doors which may be opened frequently in cold weather.	Process design modification
Add 'soft start' to all motors on presses, shears, punches, etc. which have surge load/unload characteristic loads to permit motor downsizing, resulting in higher motor efficiencies.	Control technology addition
Add 'Nortic' power factor controllers on motors on presses, shears, punches, etc. to give higher power factors.	Control technology addition

Description of ECO	Classification and Remarks
Blasting Booths	
Segregate the collection of hazardous and nonhazardous wastes from blasting booths by using different collection boxes, trucks, and collection procedures.	Operational modification
In blasting booths only low-pressure compressed air is needed for the air support function in the rubber suits used by workers in blasting booths. It may be more economical to supply this air from a small portable air compressor at the site.	Process design modification
Optimize the pressure of the compressed air used for blasting. Is 100-psi air really necessary?	Operational modification
Building 670—Radome Repair	
Consider replacing old electric baking ovens with gas-fired ovens.	Fuel substitution
HVLP paint spray guns are used for painting, but the painters need to be trained to use them properly with high-solids-content paint to avoid using more paint than is necessary.	Operational modification
Depainting C-130s (Building 50)	
Building is air-conditioned (AC) on once-through basis when painting is being done. Is this necessary? C-141s and F-15s are not painted in air-conditioned buildings. a. Turn temperature setpoint up to maximum. b. Cool workers with air-cooled suits if worker comfort is primary reason for AC. c. Cool paint if paint might be too hot otherwise.	a. Operational modification b. Process design modification c. Operational modification

Table 29. Prioritized list of process ECOs for Air Force Bases

Description of ECO	Energy Savings MBtu/yr*
a. Annual Energy Savings	
Keep doors of aircraft-repair hangars closed as much as possible in the heating season.	91,300
Replace conventional-source heaters in hangars and high-bay shop buildings with gas-fired infra-red heaters [7]. (17 hangars and 22 shop buildings)	16,729
Eliminate the use of steam for heating plating tanks (for example, install small natural gas burner system on each tank requiring heating). (Build.142)	10,738
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss. (Build 142)	10,630
Evaluate a possible reduction in allowable ventilation rate for paint booths with the use of HVLP spray guns (less overspray and emissions). (4 booths)	5,550
Replace air agitation with electric agitators in tanks.	4,320
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss. (4 tanks) (Build.180)	1,400
Eliminate the use of steam for heating treatment tanks (for example, install small natural gas burner system on each tank requiring heating). (4 tanks) (Build.180)	1,390
Convert water wash booths to dry filter for particulate control. (4 booths) (Build 180)	960
Install automatic dampers to close exhaust ducts when fans are de-energized.(4 booths) (Build.180)	800
Reduce 100% overplating (to compensate for grinding) to 40-60%.	689
Work load does not justify keeping both furnaces with endothermic atmosphere (nos. 6 and 8) turned on. Consider scheduling production so that No. 8's workload at 1600 °F is done in No. 6 in the morning when it is at this temperature before it is heated up to 2000 °F. Keep No. 8 turned off (not just down).	500
Convert water wash booth to dry filter for particulate control. (Build. 670)	240
Install automatic dampers to close exhaust ducts when fans are de-energized. (Build.670)	200
Consider leaving furnace 6 turned down on weekend schedule for 2 days during the week to save energy; workload does not require this furnace to be turned up 5 days/week.	100

b. Payback	
Description of ECO	**Payback year**
Reduce 100% overplating (to compensate for grinding) to 40-60%.	—
Evaluate a possible reduction in allowable ventilation rate for paint booths with the use of HVLP spray guns (less overspray and emissions). (4 booths)	—
Keep doors of aircraft-repair hangars closed as much as possible in the heating season.	—
Work load does not justify keeping both furnaces with endothermic atmosphere (nos. 6 and 8) turned on. Consider scheduling production so that No. 8's workload at 1600 °F is done in No. 6 in the morning when it is at this temperature before it is heated up to 2000 °F. Keep No. 8 turned off (not just down).	—
Consider leaving furnace 6 turned down on weekend schedule for 3- or 4-day weekends to save energy; workload does not require this furnace to be turned up 5 days/week.	—
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss. (Build 142)	0.1
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss. (4 tanks) (Build.180)	0.1
Convert water wash booths to dry filter for particulate control. (4 booths) (Build 180)	0.2
Convert water wash booth to dry filter for particulate control. (Build. 670)	0.2
Install automatic dampers to close exhaust ducts when fans are de-energized. (4 booths) (Build.180)	1.9
Install automatic dampers to close exhaust ducts when fans are de-energized. (Build.670)	1.9
Replace air agitation with electric agitators in tanks.	2.2
Eliminate the use of steam for heating plating tanks (for example, install small natural gas burner system on each tank requiring heating). (Build.142)	4.4
Eliminate the use of steam for heating treatment tanks (for example, install small natural gas burner system on each tank requiring heating). (4 tanks) (Build.180)	4.4
Replace conventional-source heaters in hangars and high-bay shop buildings with gas-fired infra-red heaters [7]. (17 hangars and 22 shop buildings)	5.0

*Estimates of energy savings for application of ECOs to Robins Air Force Base.

about 2 percent. The total energy savings are about 158,284 MBtu/yr, to be compared to a total energy consumption of 1,903,549 MBtu—about 8 percent.

It should be noted that this list of ECOs is by no means comprehensive. Table 28 contains a number of suggestions that could not presently be quantified, and a number of these opportunities, which should be evaluated in detail at a later date with additional information, should lead to additional energy savings.

3.3 Naval Ship Yards (Norfolk Naval Ship Yard)

From 18-22 September 1995, the project team visited Norfolk Naval Ship Yard (NNSY) in Norfolk, VA, as a representative Navy industrial facility. The primary industrial activities carried out in Naval ship yards are to repair and overhaul Navy ships.

NNSY works on both nuclear and nonnuclear ships. About 18 months before a ship is scheduled for an overhaul, a "work package" is developed that details the work to be done, including mechanical, electrical, and structural overhaul. A schedule is developed and the critical paths are identified. The work includes both shop work and work in place on board ship. Work to be done in the shop involves removing components; overhauling, reassembling and testing; and reinstalling them. If possible, it is preferable to work on components in place on the ship.

As the result of the visit, data were collected on a variety of processes, mainly in the general categories of spray paint booths, heat treating, electroplating, and abrasive blasting. Data were also collected on several processes perhaps unique to the Navy: (1) pipefitting, (2) shipfitting, (3) boilermaking (the fabrication and repair of large metal structures such as pipes, boilers, heat exchangers, parts of ships, etc.), and (4) motor rewinding. However, these processes involve a number of standard operations, such as metal working, welding, cleaning, and various types of heat treating, including curing of coatings.

A number of these processes at NNSY were found to be quite different from those carried out at either Anniston Army depot or Robins Air Force Base. Different materials and process conditions are involved in the Navy processes. For example, a great deal of painting is carried out on ships at dockside rather than in large paint booths or hangars. Painting is generally carried out with airless sprayers, which have different characteristics from conventional or HVLP guns. The overall infrastructure of supplying energy via large centralized supply systems is, of course, similar to those found at the other DOD facilities, although NNSY has an unusual

situation regarding energy supply with the central systems being operated by a different entity, with significant costs for steam and electricity.

Utilities are delivered to NNSY by the Navy Public Works Center in Norfolk, which is in charge of all fuels and utilities delivered to Navy installations in the area. Steam is generated via a power plant that uses refuse-derived fuel (RDF) collected from the area. The RDF plant is expensive to operate, and its costs are allocated to the various Navy installations, which are charged a high cost for steam and power as a result. Some electricity is provided by Virginia Power as well, but the cost of this power is rolled in with the cost of power from the RDF plant. It is not clear how these cost accounting practices may affect the evaluation of ECOs for industrial processes. If energy consumption is reduced at NNSY, then the fixed costs for power and steam production and the costs for the RDF fuel may simply be allocated to a smaller number of kWhs and Btus to keep the total energy costs for NNSY relatively constant.

As a result of the visit to NNSY, the site-visit team recommended a number of energy conservation opportunities to the shipyard personnel in their energy supply systems and their industrial processes. Because the processes conducted at NNSY are low-temperature processes using relatively little thermal energy, like those at the other sites visited, there is generally no waste heat that could be recovered. The recommendations tended to focus on changes in process operating procedures (for example, revising the operating procedures for curing motor windings to save time and energy, and scheduling production in heat treating so that unneeded furnaces can be kept turned off), standard recommendations that needed to be re-emphasized (use infra-red heating in industrial areas), and research into promising new technologies.

3.3.1 Energy and Environmental Data

3.3.1.1 Energy Data. Data on annual consumption of different forms of energy and types of water at NNSY are shown in Table 30. Historical data on consumption of electricity are shown in Figure 3.

NNSY is beginning to collect data from electrical meters on individual buildings. These data for buildings that encompass process areas can be used to relate and evaluate consumption of electricity for types of processes. In NNSY's analysis of electricity, electrical consumption is broken down into the categories of general, production, ship, and overhead. General includes administrative and support buildings and functions, industrial wastewater treatment plant, supply of compressed air, etc. Production includes all processes and industrial shops. Ships in the shipyard, with

Table 30. Annual consumption of energy and water/sewage at NNSY.

Period	Electricity		Freshwater		Steam		Sewage		Saltwater	
	kWh	M$	kgal	M$	MBtu	M$	kgal	M$	kgal	M$
FY93	190,325,577	14.227	791,295	1.899	829,067	13.472	590,574	1.618	4,119,954	1.689
FY94	185,612,778	14.199	599,007	2.007	795,950	13.523	305,020	0.946	4,015,959	1.727
8/94-7/95 (latest 12-month period)	163,495,830	12.183	437,850	1.759	651,532	10.954	211,135	0.672	3,782384	1.689

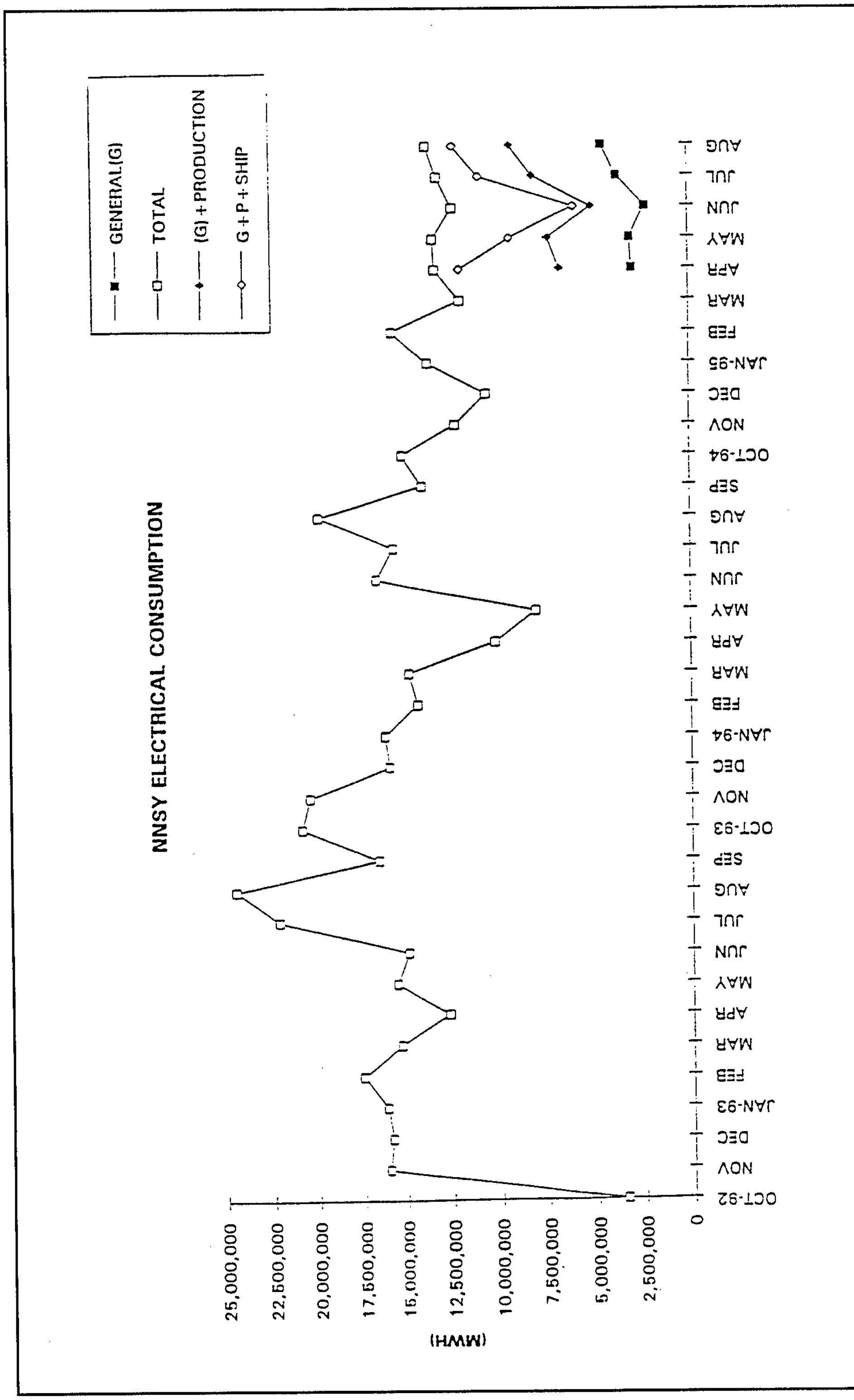


Figure 3. Historical data on electricity consumption at NNSY.

their boilers and power plants usually shut down, get their power from the yard, which is metered. Data which illustrate this breakdown of electrical consumption are shown in Table 31. Data of this type for electrical consumption, related to processes which were surveyed on the site visit (described below), are shown in Table 32.

***3.3.1.1.1* Utility Rates**. NNSY is charged the following rates (FY95) for utilities by the Navy Public Works Center in Norfolk:

AC electricity	$74.00 per MWh (no demand charge)
Water	$4.16 per kgal
Clean steam	$16.79 per MBtu
Sewage disposal	$3.20 per kgal
Saltwater	$0.45 per kgal

***3.3.1.1.2* Pipefitting Shop**. The work of the pipefitting shop involves cutting old pipes from ship systems (after they are drained, etc.) and fabricating new pipe. New pipes are fabricated by: (1) cutting new pipe lengths, (2) welding on fittings, (3) brazing the welded connections if necessary, and (4) bending the pipe to meet the specifications. The shop currently is operating for two shifts a day and weekends as necessary. The cost for steam for heating is allocated on the basis of area. There is no air conditioning (the usual situation in shops of this type). Stratification is probably a problem with the distribution of heat.

Steam is used in coils for heating cleaning vats, to about 140 °F. The vats contain sulfuric acid, nitric acid, and trisodium phosphate. Pipes are cleaned of grease and flux in these vats. Each vat is approximately 4,000 gal in volume. The mist from the vats is collected in an exhaust system and scrubbed. A control system could be used on the exhaust fans to control their load.

Wave guides for radar systems are brazed by dipping them in a salt bath heated in a furnace to 1300 °F. The furnace requires 55 kW of heating. The aluminum brazing salt is a sodium fluoride mixture. The salt bath has no cover.

Standard "pipe details" are used as a measure of production—about 100/week. Quality is accounted for in terms of fabrication problems and detail problems, a few percent being typical.

***3.3.1.1.3* Boilermaking Shop**. The products of the boilermaking shop are tanks, platforms, and rebuilt coolers (heat exchangers). Shop operations involve metal cutting, grinding, and welding. There are both pneumatic and electric

Table 31. Breakdown of electrical consumption at NNSY by category of use (in kWh).

Month (1995)	General	Production	Ship	Overhead	Total
April	2,896,393	3,718,021	5,246,660	1,248,695	13,109,769
May	2,985,693	4,191,106	2,083,630	3,937,139	13,197,568
June	2,173,122	2,840,047	875,380	6,306,627	12,195,176
July	3,669,939	4,309,486	2,865,290	2,105,019	12,949,734
August	4,458,925	4,732,406	2,944,180	1,373,097	13,508,608
Total	16,184,072 (24.9%)	19,791,066 (30.5%)	14,015,140 (21.6%)	14,970,577 (23.0%)	64,960,855 (100.0%)

Table 32. Consumption of electricity for selected process areas

Code	Bldg.	Description	Electricity Consumption, kWh*						
			3/95	4/95	5/95	7/95	8/95	Total (5 months)	Estimated 12-Month (Total)
C-910	174	Air compressors	171,260	679,094	421,460	614,916	1,402,492	3,289,222	7,894,133
C-910	273	Air compressors	222,700	129,700	165,100	109,200	157,100	783,800	1,881,120
C-911	163	Boilermaking and shipfitting	327,100	333,920	242,300	334,600	369,700	1,607,620	3,858,288 (7.8%)
C-956	202	Pipefitting	946,362	182,160	294,200	338,400	428,800	2,189,922	5,255,813 (10.6%)
C-951	510	Motor rewinding	759,320	527,880	967,000	784,680	822,240	3,861,120	9,266,688 (18.6%)
C-971	1499	Blasting/painting	40,960	39,680	55,040	30,720	39,680	206,080	494,592 (1.0%)
C-931	195	Plating	0	53,760	80,640	89,280	68,160	291,840 **	875,520 (1.8%)
		Total production	**3,790,155**	**3,718,021**	**4,191,106**	**4,309,486**	**4,732,406**	**20,741,174**	**49,778,817 (100%)**

* Data for June 1995 not available.
** Apparent 4-month total.

grinders, hydraulic presses (currently not used much), and cutting shears. The process involves cutting, bending, grinding, inspecting, and cleaning. Boiler tubes are cleaned of preservatives by being boiled in a detergent solution (Penesolve PenPower 150H) for 4 hours. The cleaning vats are about 30 ft in length by 2 ft by 3 ft in depth. There are four to six big tube jobs a year. Cu-Ni tubes for coolers do not have preservatives and require no cleaning; they are just cut to length and the ends are smoothed.

***3.3.1.1.4* Plating Shop**. The plating shop contains an assortment of chemical vats used for plating operations (cleaning, rinsing, preplating, plating, etc.) for various metals. The tanks are heated with steam and agitated with compressed air generated by a 40-hp (1300 cfm) compressor in the shop. The compressor is not equipped with a variable frequency drive so that excess air is simply blown off. Production is measured on the basis of plated area. (Recent production logs show about 152 sq in./day, at about 22.4 kWh of electricity for plating/sq in.)

Countercurrent rinsing is used with makeup to the plating bath being supplied from the first rinse. The tanks were uncovered;—balls and foam were said to create problems. Small plating types of metal recovery systems were used to recover silver and copper from waste solutions from the cyanide baths. Hard chrome plating was done to double the specification thickness to allow for grinding. There were seven 15-hp blowers used for ventilation. Exhaust stacks were equipped with demisters and scrubbers. The shop is operated for one shift.

***3.3.1.1.5* Shipfitting Shop**. This shop contains various pieces of heavy equipment for fabricating large ship components from steel plates and similar materials. There is a computer-controlled thermal plasma (oxygen and acetylene) cutting arc for cutting plates. The cut plates are conveyed through the shop on a large rolling conveyor. The plates are drilled, punched, rolled, shaped, pressed, planed, etc. into various ship components. Electricity is the main source of energy for these processes.

There are three ovens for heat treating fabricated components. Most furnaces used currently are electric. For example, there is an electric Lindberg furnace that can go up to 2100 °F (usually operated at 1600 °F, three cycles per load, each cycle 12 hours), consumes 100 kW of power, and has a capacity of 1500 lb. (It also has a poor seal on the door.) There is an electrically heated fluidized-bed furnace with a controlled atmosphere. There is a large furnace (Lindberg electric car-bottom furnace) for heat treating ship propellers, which takes 800 kW of power. It is used 20 to 30 times a year on a 24-hour cycle.

There is a machine for depainting anchor chain by blasting it with steel shot. One ton of hazardous waste is generated each time that it is used. Different types of paint have been used for painting anchor chain, but the durability of the coating is a significant problem. Paint used currently is Ameron epoxy paint.

3.3.1.1.6 **Motor Rewinding Shop**. Rewinding motors is a significant process activity in a ship yard. After a motor has been received, it is tested. A motor that fails the test is torn down, and its parts are engraved (small amount of compressed air for the engraver). The motor parts are then washed with steam, using 125-psia steam directly, in a process that generates hazardous waste. The parts are then dried in an oven at around 300 °F, an operation that takes 12 hours. This amount of time required for drying is a bottleneck in the process. A parts washer with a vacuum drier has been ordered (to reduce time for drying and hazardous waste, and to improve quality and safety).

Other operations involve: (1) burning off the old wiring (heated in an oven to 800 °F), (2) rewinding the motor, (3) applying new varnish (two or three varnish-bake cycles, each at 300 °F for 8 hours to cure the varnish), (4) assembling it, and (5) testing the finished motor. A question raised was why the bake cycle after each varnish dip takes 8 hours, when the specification sheet on the new type of varnish now being used indicates that the varnish should cure in 2 hours. Shortening each bake cycle would save a significant amount of time and energy.

NNSY has both gas (the older ovens) and electric ovens for the drying, burnoff, and baking operations. The gas ovens typically use 400,000 Btu per hour, and the electric ones use 51 to 60 kW each. A small amount of compressed air is used for pneumatic tools (but this use can probably be eliminated to eliminate the compressed-air line running to and in the building). The building is heated with central steam. About 900 motors are rebuilt in a year (38 percent are rewound; the rest are simply refurbished).

3.3.1.1.7 **Painting and Blasting Shop**. The painting and blasting shop is used for painting ship components with two shifts. There are two large blasting booths, which are used three quarters of the time. The air supply for the workers is filtered air from the central supply. The dust from each one is collected in a baghouse. New bags are installed once a year. Central compressed air is used for the blasting. Less pressure on the air would slow the blasting operation. Two smaller booths are used for smaller pieces—glass beads for electrical parts (does not grind away the metal) or aluminum oxide. Costs of blasting and painting are assessed by measuring the area blasted or painted ($1.20/sq ft per coat for painting and $3.50/sq ft for blasting [a slower operation]).

In the large paint booth, there is a water wash, but no circulation pump. The collected paint sludge is skimmed off the top, and the pits are cleaned once a year by the painters. Airless paint spray guns are used with pneumatic paint pumps (cheaper than electric pumps with low maintenance). High-solids epoxy paints are used.

3.3.1.2 Environmental Data. The yard is in the process of performing a Title V inventory. There are 50 to 60 sources of emissions identified at the shipyard, including paint booths (emissions based on paint throughput, most booths are grandfathered), plating (emissions based on amount of metal deposited—chromium, but not much of this), and the RDF plant, which is a significant contributor. Operating under a consent order, the RDF plant is working to improve its control of dioxins and furans emissions, which are attributed to the combustion of chlorinated plastics. Exotic, unique, expensive ($50M) control equipment (lime slurry injection) is being installed to abate these types of emissions from the RDF plant. The plant has a precipitator, which is being taken out; the plant is moving to a fabric filter.

VOC emissions are generated from the use of 150 tons of coatings used per year. Solvents are used for cleaning (23 tons). There are emissions from the use of 408,000 gal of gasoline; gasoline storage tanks are equipped with Stage I recovery systems.

With respect to fuels used directly on base, about four million cu ft of natural gas is bought each year, at a cost of about $6.95/MBtu. It is burned mostly in Building 163 (gas-fired furnaces). There are two barge-mounted oil-fired boilers for generating steam for ships at berth. These boilers consume No. 2 fuel oil—about 1,373,000 gal a year.

Coal is a secondary fuel for the RDF plant (a total of about 24,158 tons). The coal is low-sulfur (0.3-0.5 percent).

Used blasting media are the largest hazardous waste stream with paint comprising the second largest. Paint booths are being converted to dry filters.

3.3.2 Analysis of Data

3.3.2.1 Energy Data. The first point to note about the cost of energy at NNSY is that the unit costs of electricity and steam are both high compared to the unit costs at Anniston and RAFB. In addition, these unit costs are more nearly equal on a Btu basis than is usually the case. Also, natural gas is much more expensive to NNSY than to the other bases surveyed, although its cost is still much less than the other forms of energy. The use of more natural gas at NNSY and its substitution for other

fuels would lower NNSY's energy bill, but the use of gas at NNSY is perhaps restricted because of the constraints surrounding the supply of power and steam from the RDF plant.

The data in Table 31 on the breakdown of electrical consumption shows that the consumption of electricity for process purposes is only 30 percent of the total consumption at the shipyard. This figure excludes the consumption of electricity for the production of compressed air, which is included in the "general" category of use. From the data in Table 32, compressed-air production accounts for about 6 percent of the total consumption of electricity. The major uses of compressed air at the shipyard are sandblasting, operating machines in the sheet metal shop, and spray painting.

The relative importance of the electrical consumption of the processes surveyed on the site visit, compared to the total consumption for production, is indicated in Table 32. Motor rewinding consumes almost 20 percent of the electricity used for production at the shipyard. Boilermaking, shipfitting, and pipefitting consume almost another 20 percent. Plating consumes relatively little electricity, compared to the total. Blasting and painting apparently consume relatively little electricity, compared to the total, but the figure shown in the table for these processes does not include the electricity consumed in the form of compressed air. In addition, the thermal energy used to heat the make-up air for blasting and painting booths is not considered in this discussion of electricity.

The data on monthly consumption of steam were analyzed to estimate the proportion of steam used for heating and nonheating uses (the year-round baseload is assumed to represent the process uses). Based on the amount of steam used monthly during the nonheating season and assumed to represent an essentially constant process load, it is estimated that approximately 73 percent of the steam consumed at NNSY is used for process uses (see Table 33). Steam consumption can fluctuate significantly with the number of ships in the yard.

Table 33. Analysis of steam use at NNSY, August 1994–July 1995 (latest 12-month period).

Season	No. of Months	Total Steam (MBtu)	Percent of Total Steam	Monthly Average (MBtu/mo.)
Heating (November - April)	6	414,610	63.6	69,101
Nonheating (May - October)	6	236,922	36.4	39,487
Totals	**12**	**651,532**	**100.0**	**54,294**

Process use = 39,487 MBtu/mo x 12 mo = 473,844 MBtu/yr (72.7% of total annual steam)
Heating use = 651,532 MBtu/yr - 473,844 MBtu/yr = 177,688 MBtu/yr (27.3% of total annual steam)

3.3.2.2 Environmental Data. The environmental concerns at NNSY are similar to those voiced at Anniston Army Depot and Robins Air Force Base: used blasting media, paint wastes, solvents, and plating emissions. The same types of potential measures for dealing with these wastes and emissions can be considered for implementation at NNSY.

NNSY apparently does not have as many vapor degreasers as were seen at Anniston and Robins, but again, emissions of trichloroethylene emissions will be reduced significantly with the elimination of most of the vapor degreasers, which are slated to disappear.

To reduce HAP emissions resulting from painting operations by using less paint, a low-cost measure requiring little capital expense would be to switch from airless spray guns to HVLP spray guns, which are somewhat more efficient. The painters should then be trained to use this type of spray gun properly. The environmental people at NNSY indicated that they were considering this measure.

The most cost-effective way to reduce the VOC emissions resulting from painting operations is probably to reduce the solvent content of the paints used, rather than to try to capture the emissions. Paint and coating reformulation projects are currently being pursued with this objective (Day and Zimmerman, and SAIC 8 February 1991). Until candidate coatings have been developed to meet requirements, it is not possible to estimate potential reductions in VOC emissions with this approach. Again, the environmental people at NNSY indicated that they were continually evaluating new types of paints and coatings with this objective in mind.

The other major environmental concern at NNSY, the use and the disposal of used, contaminated blasting media, can perhaps be addressed with a variety of potential measures: (1) use of different blasting media leaving no residue other than paint chips (e.g., frozen CO_2 particles) or a residue which is easily separable from paint chips (e.g., high-pressure water jets) or (2) better control of emissions with more efficient collection systems or increased capability to recycle the collected blasting media.

3.3.2.3 Facility Conditions. Another objective of making the site visits in this task was to examine facility conditions. The general impression of the physical condition of the processes at NNSY was that they have been fairly well maintained. However, this Naval installation is much older than the Army and the Air Force bases visited (it was established before the American Revolution). Much of the process equipment observed on the site visit was quite old, particularly the metal-fabricating equipment (presses, punches, rolls, etc.), but these machines apparently have a long lifetime if

they are maintained. Many of the paint booths were quite old. There were a number of heat treating furnaces dating back to before World War II. The test panel used to test motors was 25 years old and in need of replacement.

On the other hand, new types of equipment were observed: the thermal plasma plate cutter, welding equipment dating to 1989, the refurbished cleaning facility in the pipefitting shop, etc.

The steam lines appeared to need a great deal of work. A number of significant leaks were observed. A number of compressed air leaks were noticed as well during the survey of the process buildings.

3.3.3 PEPR Opportunities With Estimations of Investment and Savings

As the result of observing the process operations at NNSY and collecting process data, a number of ideas for conserving energy in the process operations were conceived. These ECOs are listed below. Where sufficient information was available for analyzing these ECOs for their potential for NNSY, the results of these analyses are also described in this section.

3.3.3.1 Descriptions of ECOs.

3.3.3.1.1 General and Central Supply Systems.

1. Optimize boiler pressure at lower levels using point-of-use pressure control with summer setback (0.1 to 0.2 percent savings/10 psi drop).

2. Replace steam space heaters in most buildings with direct gas-fired unit heaters (rotary convection and infra-red).

3. Optimize pressure of compressed air at lower levels using point-of-use pressure control (1 percent savings/2 psig drop).

4. Decommission and/or idle selected segments of the steam system where piping runs in parallel or users are fed from two directions.

5. Switch hand tools from pneumatic to electric (battery or cord) where possible.

6. Install circulating fans in high-bay buildings to destratify the heated air in wintertime, ventilate in summertime.

3.3.3.1.2 Pipefitting Shop.

1. Add a lid to 1300 °F sodium fluoride salt bath.

2. Replace sodium fluoride salt bath with alternate technology for salt brazing.

3. Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss.

4. Optimize time and temperature of the pickling (cleaning) operations.

5. Add automatic on/off controls to ventilation exhaust fans on tanks in pipe cleaning area.

6. Consider VFD on ventilation exhaust fans.

7. Install automatic dampers to close exhaust ducts when exhaust fans are de-energized.

8. Reduce heat loss from vertical skylights (styrofoam and window gaskets).

3.3.3.1.3 Boilermaking and Shipfitting Shops.

1. Implement just-in-time supply of boiler tubes from suppliers, specifying clean tubes to eliminate need for Cosmolene rust protection and need to clean tubes.

2. Convert electric annealing/heat treating furnaces to natural gas where feasible.

3. Add "soft start" to all motors on presses, shears, punches, etc. that have surge load/unload characteristic loads to permit motor downsizing, resulting in higher motor efficiencies.

4. Add "Nortic" power factor controllers on motors on presses, shears, punches, etc., which have surge load/unload characteristic loads, to give higher power factors.

5. Install improved seals on furnace doors. Since a furnace operates at a temperature higher than ambient, air may be drawn into the combustion chamber through any cracks and crevices due to the stack effect. Such air allowed to infiltrate into the furnace is detrimental to the furnace efficiency. Energy can

be saved through the use of effective door seals (for example, ceramic "tadpole" seals).

6. Apply ceramic coating to firebrick. Spray-on ceramic coatings can increase the surface emissivity of the refractory surface to above 0.95. The increased radiative transfer resulting from this increased emissivity can yield savings in fuel. Although such savings cannot be accurately quantified, energy savings from this measure are conservatively estimated as 15 percent of burner fuel input.

7. Consider converting electric ovens/furnaces to natural gas. Gas-fired furnaces can be cheaper to operate than electrical furnaces because thermal energy obtained from gas is cheaper than that obtained via electricity.

8. Use newer types of furnaces for heat treating. For heat treating metals, there are newer types of ovens and furnaces that may be used. These newer systems, which include induction and indirect resistance furnaces, are more energy-efficient and therefore should be evaluated for possible application to Army processes.

9. Fix compressed air leaks; e.g., two major leaks in Shop 11: 1-1/2 in. hose (wastes $12,600/yr @ est. 100 cfm) and at air fitting on furnace ($6,300/yr @ est. 50 cfm).

3.3.3.1.4 Electroplating Shop.

1. Float polypropylene balls or use lids on top of solutions to reduce heat losses. Uncovered, hot solutions in plating tanks can lose a significant amount of energy through increased evaporation and heat loss. Balls floated on top of the hot solutions or moveable lids installed onto heated tanks can reduce these heat losses by a significant amount (a factor of perhaps half).

3. Eliminate use of steam for heating tanks and replace with natural gas. The use of steam—particularly the 125 to 150 psi steam from the central steam supply with all of the inefficiencies of that system—is an inefficient and unnecessary way to heat the solutions in plating tanks. Systems are available to use natural gas for heating plating tanks directly, with an individual burner system and temperature control for each tank. The other major use of steam in the electroplating shop is for space heating. This use of steam can be eliminated by using gas-fired, infra-red radiant heaters for space heat.

4. Replace air agitation with electric agitation in tanks. Compressed air is typically used for agitating solutions in plating tanks. Although the use of compressed air for this purpose is convenient, compressed air is a very inefficient way to use energy. Consider using electric agitators to eliminate the use of compressed air for agitating the baths.

5. Reduce 100-percent overplating. Frequently, parts are overplated up to 100 percent to allow for an adequate thickness for uniform grinding. However, this amount of overplating would appear to waste energy and materials; overplating should be controlled at a lower level—say, 50 percent—for conservation.

6. Install plating waste concentrators to recover and recycle waste solutions. Waste plating solutions are usually sent to the industrial wastewater treatment plant. These solutions can be recycled by concentrating them. The concentrate is returned to the plating tank and the water is returned to the rinse tank.

7. Install a variable frequency drive (VFD) on the air compressor in the plating shop. At present, excess air that is not needed is simply blown off.

8. Install automatic dampers to close exhaust ducts. There typically are a large number of exhaust fans and ducts in a plating shop; each hot tank has a ventilation duct that collects fumes and emissions. However, whenever a tank is unused and its fan is turned off, a draft through the open duct causes energy to be lost. A damper that closes automatically if the fan is de-energized would prevent this draft loss.

9. Install variable frequency drives on exhaust ducts. The ventilation load in a plating shop varies as a function of how many tanks are being used at any one time. It is inefficient and wastes energy to keep the ventilation fan running at a constant speed. If the fan is equipped with a variable frequency drive, the fan speed can vary in response to the load, saving energy.

10. Find alternate plating solutions/technologies to replace cyanide solutions.

11. For small batches install and use small plating tanks.

3.3.3.1.5 Motor Rewinding Shop.

1. Replace steam space heaters with gas-fired heaters.

2. Consider alternative technologies to eliminate manual steam cleaning and subsequent long drying time for motor parts:
   a. Power washer and vacuum drier (note that present analysis does not include credit for savings in steam usage)
   b. Blasting with CO_2 pellets to clean motor parts (eliminate steam and wastewater, and the requirement for drying)—NNSY has prior experience with evaluation of this technology.

3. Eliminate the use of compressed air in the shop, and decommission the line to/in the building. Compressed air is a very inefficient power source, with lots of wasteful leaks associated with practically every line; no uses in the shop require 100-psi air.

4. Reduce the time for the baking step after each varnish dip. The spec sheet for the new varnish indicates a curing time of 2 hours at 300 °F. It would seem unnecessary to bake a varnished part for 8 hours. The approved procedure perhaps needs to be updated for the different varnish. For a reduction in baking time of 4 hours (from 8 to, say, 4), the savings could be more than $10,000 a year.

5. Supply gas to the power washer for heat instead of electricity or steam.

***3.3.3.1.6* Blasting and Painting Shop**.

1. Consider the use of HVLP spray guns in place of airless spray guns for energy conservation, reduced paint usage through a greater transfer efficiency (the main benefit), less pollution (less paint waste, and fewer VOCs emitted to the atmosphere), and less frequent changing of the dry filters with lower costs. Investigate the use of HVLP guns for specific types of paints and specific spray paint booths and painting applications (e.g., particularly for work on the waterfront).

2. Consider the use of blasting with CO_2 pellets for specific blasting applications.

3. Replace the (currently nonfunctioning) steam heaters with gas-fired heaters. (Suitable ones *can* be found for the atmosphere in this building.)

4. Evaluate the use of alternate, less hazardous (lower VOC content) paints.

5 Train the painters in the proper use of spray paint guns, particularly if adopting HVLP guns.

6. Investigate the use of electrostatic painting to reduce the amount of overspray and hence the amount of particulate that: (1) is wasted, and (2) has to be collected by the dry filters.

7. Decrease the amount of air circulation. The specifications for air circulation for an operating booth are generally subject to regulations regarding minimum air flow. However, since the booth was originally designed, the air circulation system may not have been maintained, and the amount of air being circulated may be more than is required. The fans may be oversized and are circulating more air than is necessary. In addition, if low-volatile-content paints are being used, less VOCs are being emitted that have to be ventilated from the booth. Thus, the amount of air being circulated should be measured and controlled to the minimum. Perhaps the amount of air being circulated can be reduced.

8. Install automatic dampers to close the exhaust ducts. Whenever the air circulation system in the booth is turned off, there is a draft through the open ducts to lose heat. Install automatic dampers in the exhaust ducts to close off the ducts whenever the exhaust fans are not running.

9. Convert water wash booths to dry filters for particulate control.

10. Use different types of coatings. The operation of spray paint booths can be improved significantly with the introduction of new and different types of paints or coatings, which may have fewer emissions or better quality, or lead to greater productivity. The type of paint used in a spray paint booth might have a significant effect (either positive or negative) on energy usage as well as a significant impact on emissions. For example, the use of powder coatings, waterborne paints, or radiation cured coatings could reduce VOC emissions significantly, but lead to greater energy usage by requiring the use of ovens for baking, drying, or curing. The use of a newer paint or coating in an existing spray paint booth would have to be researched to determine if the booth could handle such a coating. In addition, research and development would be required to investigate the use of newer coatings for military applications and to change product specifications affected by the use of such coatings.

3.3.3.2 Analyses of ECOs. The ECOs identified for NNSY for those process areas visited during the site visit, and analyzed are listed in Table 34. The results of the analyses are also shown in the table. Some other process ECOs evaluated in previous studies (Day and Zimmerman, and SAIC 7 September 1990; Earth Technology Corp. vol I&II November 1993) are also included so that they or similar ECOs could

be recommended to other Naval shipyards. ECOs for which insufficient information was available for their analysis are listed in Table 35.

3.3.4 Prioritized List of Recommendations for Naval Ship Yards To Implement

Table 36 is a prioritized list of the ECOs evaluated for shipyards, based on Norfolk; Table 36a is prioritized with respect to annual energy savings and 36b with respect to payback period.

In this table for shipyards, savings that could be achieved by overhauling the central steam distribution system (finding and fixing leaks and traps, etc.) are not included, but their potential is, or should be, well recognized for their payback and energy savings. The sum total of the process ECOs in Table 36 saving thermal energy is 56,424 MBtu/yr, to be compared to a total of 651,532 MBtu of thermal energy (steam) consumed annually by Norfolk Naval Ship Yard (see Table 30)—about 9 percent.

The sum total of process ECOs saving electricity is 20,489 MBtu/yr, to be compared to a total of 558,011 MBtu of electricity consumed annually by Norfolk Naval Ship Yard—about 4 percent. The total energy savings are about 76,913 MBtu/yr, to be compared to a total energy consumption of 1,209,543 MBtu—about 6 percent.

There are several reasons why the process-oriented ECOs at Norfolk Naval Ship Yard in Table 36 apparently comprise a relatively small portion of the total energy consumption, especially compared to the potential savings at Anniston and Robins. Process energy apparently is a small portion of total energy consumption at Norfolk to begin with. Table 31 indicates that only 30 percent of electricity consumption is for production processes, and ships in dock account for a significant unmeasured amount of thermal energy. Shipyards apparently have significant overhead activities that consume energy. In addition, the central steam and compressed air distribution systems at Norfolk waste a great deal of energy, which boosts the total energy consumption significantly. Finally, it should be noted that several significant ECOs that increased the listed potential savings at Anniston and Robins were not evaluated for Norfolk: overhauling the steam distribution system (Anniston), more efficient motors (Anniston and Robins), and gas-fired heaters in shop buildings (Robins). Similar types of ECOs could be proposed for Norfolk, but additional data would be needed for their evaluation.

It should be noted that this list of ECOs is by no means comprehensive. Table 35 contains a number of suggestions that could not be quantified at the present time, and a number of these opportunities that should be evaluated in detail at a later date with additional information and should lead to additional energy savings.

Table 34. Summary and evaluation of process ECOs at Norfolk Naval Ship Yard.

Description of ECO	Capital Cost $	O&M Saving $/yr	Energy Saving MBtu/yr	Payback yr	Return on Investment%	Savings-to-Investment Ratio (SIR)	Classification and Remarks
Electroplating Shop							
Replace air agitation with electric agitators in tanks.	28,000	na	630[1]	2.2		6.9	Technology replacement
Reduce 100% overplating (to compensate for grinding) to 40-60%.	0	na	466[1] 689[2]	—		—	Operational modification
Install VFD on air compressor in shop.	4,000	na	184	1.1		14	Process design modification
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss.	500	na	1,100[1] 2,100[2]	0.1		200	Operational modification
Eliminate the use of steam for heating plating tanks (for example, install small natural gas burner system on each tank requiring heating).	31,000	na	-300[1] 2,000[2]	1.1		4.7	Process design modification
Motor Rewinding Shop							
Consider power washer and vacuum drier to eliminate manual steam cleaning and subsequent long drying time for motor parts [8].	250,000	56,705	415	5.0	23.0	1.6	Technology replacement
Reduce time for the baking step after each varnish dip (spec sheet for new varnish indicates a curing time of 2 hours at 300°F; therefore, should not be necessary to bake a varnished part for 8 hours). Reduce baking time to, say, 4 hours.	0	na	350	-	-	-	Operational modification
Blasting and Painting Shop							
Consider the use of HVLP (high-volume low-pressure) spray guns in place of airless spray guns for increased transfer efficiency and painting control (particularly for work on the waterfront).	285	21,800	12[1] 16[2]	0.0	48.0	1148	Technology replacement

Description of ECO	Capital Cost $	O&M Saving $/yr	Energy Saving MBtu/yr	Payback yr	Return on Investment%	Savings-to-Investment Ratio (SIR)	Classification and Remarks
Evaluate a possible reduction in allowable ventilation rate for the paint booth with the use of HVLP guns (less overspray and fewer particulates in air stream).	0	na	624[1] 1,387[2]	-	-	-	Operational modification
Convert water wash to dry filter for particulate control.	1,670	22,451	240	0.1	74.9	180	Technology replacement
Install automatic dampers to close exhaust ducts when fans are de-energized. (1 booth)	6,700	na	598[1] 1,224[2]	2.5	14.8	7.2	Control technology addition
Pipefitting Shop							
Eliminate the use of steam for heating plating tanks (for example, install small natural gas burner system on each tank requiring heating).	45,000	na	-450[1] 3,000[2]	1.1		4.7	Process design modification
Install circulating fans in high-bay buildings to destratify the heated air in wintertime, ventilate in summertime.	45,000	na	7,300	2.7		40	Process design modification
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss.	750	na	1,600[1] 3,100[2]	0.1		200	Operational modification
Install automatic dampers to close exhaust ducts when exhaust fans are de-energized.	1,700	na	150[1] 200[2]	1.9	17.3	11.1	Control technology addition
Boilermaking and Shipfitting Shops							
Add variable frequency drive to combustion air fan supplying air to several furnaces in forge shop [9].	6,318	na	140	8.6		1.75	Process design modification
Install circulating fans in high-bay buildings to destratify the heated air in wintertime, ventilate in summertime.	54,000	na	8,800	2.7		41	Process design modification
Central Compressed Air Supply System							
Install common computer control system to control compressor operations [9].	282,000	na	11,500	2.6		5.7	Control technology addition

Description of ECO	Capital Cost $	O&M Saving $/yr	Energy Saving MBtu/yr	Payback yr	Return on Investment%	Savings-to-Investment Ratio (SIR)	Classification and Remarks
Fix compressed air leaks 9].	16,300	na	7,090	0.1		67.6	Operational modification
Central Steam Distribution System							
Insulate exposed steam piping in Building 510 (motor rewinding shop) [9].	26,192	na	14,444	0.6		19.8	Process design modification
Install condensate piping and components to a number of buildings in the shipyard and connect to existing overhead condensate return main [9].	184,115	42,581	12,104	2.8		4.4	Process design modification

*Energy saved at the process.
**Energy saved in primary fuel, considering losses in central steam and compressed-air supply systems, and efficiency of steam generation.

Table 35. Summary of additional potential process ECOs at Norfolk Naval Ship Yard.

Description of ECO	Classification and Remarks
Electroplating Shop	
Install automatic dampers to close exhaust ducts when fans are de-energized.	Control technology addition
Optimize batch size (or use small tanks for small batches).	Operational modification
Install VFDs on exhaust fans.	Process design modification
Install VFD on air compressor in shop.	Process design modification
Find alternate plating solutions/technologies to replace cyanide solutions.	Technology replacement
Motor Rewinding Shop	
Consider alternative technologies to eliminate manual steam cleaning and subsequent long drying time for motor parts: blasting with CO_2 pellets to clean motor parts.	Technology replacement
Eliminate the use of compressed air in the shop, and decommission the line to/in the building; there are no uses in the shop requiring 100-psi air.	Operational modification

Description of ECO	Classification and Remarks
Supply gas to the new power washer for heat instead of electricity or steam.	Fuel substitution
General and Central Supply Systems	
Optimize boiler pressure at lower levels using point-of-use pressure control with summer setback (0.1-0.2% savings/10 psi drop).	Control technology addition
Replace steam space heaters in most buildings with direct gas-fired unit heaters (rotary convection and infra-red).	Technology replacement
Optimize pressure of compressed air at lower levels using point-of-use pressure control (1% savings/2 psig drop).	Control technology addition
Decommission and/or idle selected segments of the steam system where piping runs in parallel or users are fed from two directions.	Operational modification
Switch hand tools from pneumatic to electric (battery or cord) where possible.	Technology replacement
Install circulating fans in high-bay buildings to destratify the heated air in wintertime, ventilate in summertime.	Process design modification
Blasting and Painting Shop	
Consider the use of blasting with CO_2 pellets.	Technology replacement
Replace the (currently nonfunctioning) steam heaters with suitable gas-fired heaters.	Technology replacement
Train the painters in proper use of spray paint guns.	Operational modification
Install automatic dampers to close exhaust ducts when fans are de-energized.	Control technology addition
Evaluate the use of alternate, less hazardous (lower VOC content) paints.	Technology replacement
Pipefitting Shop	
Add lid to 1300°F sodium fluoride salt bath.	Process design modification
Replace sodium fluoride salt bath with alternate technology for salt brazing.	Technology replacement
Optimize time and temperature of the pickling operations.	Operational modification
Reduce heat loss from vertical skylights (styrofoam and window gaskets).	Process design modification
Add automatic on/off controls to ventilation exhaust fans on tanks in pipe cleaning area.	Control technology addition
Consider VFD on ventilation exhaust fans.	Process design modification

Description of ECO	Classification and Remarks
Install automatic dampers to close exhaust ducts when exhaust fans are de-energized.	Control technology addition
Boilermaking and Shipfitting Shops	
Implement just-in-time supply of boiler tubes from suppliers, specifying clean tubes to eliminate need for Cosmolene rust protection and need to clean tubes.	Operational modification
Convert electric annealing/heat treating furnaces to natural gas where feasible.	Fuel substitution
Add 'soft start' to all motors on presses, shears, punches, etc. which have surge load/unload characteristic loads to permit motor downsizing, resulting in higher motor efficiencies.	Control technology addition
Add 'Nortic' power factor controllers on motors on presses, shears, punches, etc. which have surge load/unload characteristic loads to give higher power factors.	Control technology addition

Table 36. Prioritized list of process ECOs for Naval Shipyards.

Description of ECO	Annual Energy Savings (MBtu*)
a. Annual Energy Savings	
Insulate exposed steam piping in Building 510.	14,444
Install condensate return system in some buildings not now connected to existing return main.	12,104
Install common computer control system to control compressor operations.	11,500
Install circulating fans in high-bay buildings to destratify the heated air in wintertime, ventilate in summertime. (Shipfitting Shop)	8,800
Install circulating fans in high-bay buildings to destratify the heated air in wintertime, ventilate in summertime. (Pipefitting Shop)	7,300
Fix compressed air leaks.	7,090
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss. hot cleaning vats in Pipefitting Shop)	3,100
Eliminate the use of steam for heating plating tanks (for example, install small natural gas burner system on each tank requiring heating). (hot cleaning vats in Pipefitting Shop)	3,000
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss. (hot vats in Plating Shop)	2,100
Eliminate the use of steam for heating plating tanks (for example, install small natural gas burner system on each tank requiring heating). (hot vats in Plating Shop)	2,000
Evaluate a possible reduction in allowable ventilation rate for the paint booth with the use of HVLP guns (less overspray and fewer particulates in air stream). (Painting Shop)	1,387
Install automatic dampers to close exhaust ducts when fans are de-energized. (Painting Shop)	1,224
Reduce 100% overplating (to compensate for grinding) to 40-60%. (Plating Shop)	689
Replace air agitation with electric agitators in tanks. (Plating Shop)	630
Consider power washer and vacuum drier to eliminate manual steam cleaning and subsequent long drying time for motor parts. (Motor Rewinding Shop)	415
Reduce time for the baking step after each varnish dip to, say, 4 hours. (Motor Rewinding Shop)	350
Convert water wash booth to dry filter for particulate control. (Painting Shop)	240
Install automatic dampers to close exhaust ducts when fans are de-energized. (cleaning area in Pipefitting Shop)	200
Install VFD on air compressor in plating shop.	184

Description of ECO	Annual Energy Savings (MBtu*)
Add variable frequency drive to combustion air fan supplying air to several furnaces in forge shop.	140
Consider the use of HVLP (high-volume low-pressure) spray guns in place of airless spray guns for increased transfer efficiency and painting control. (Painting Shop)	16

b. Payback

Description of ECO	Payback yr*
Evaluate a possible reduction in allowable ventilation rate for the paint booth with the use of HVLP guns (less overspray and fewer particulates in air stream). (Painting Shop)	—
Reduce 100% overplating (to compensate for grinding) to 40-60%. (Plating Shop)	—
Reduce time for the baking step after each varnish dip to, say, 4 hours. (Motor Rewinding Shop)	—
Consider the use of HVLP (high-volume low-pressure) spray guns in place of airless spray guns for increased transfer efficiency and painting control. (Painting Shop)	0.0
Convert water wash booth to dry filter for particulate control. (Painting Shop)	0.1
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss. (hot cleaning vats in Pipefitting Shop)	0.1
Float polypropylene balls or other objects of suitable size on top of heated solutions in tanks to decrease evaporation and heat loss. (hot vats in Plating Shop)	0.1
Fix compressed air leaks.	0.1
Eliminate the use of steam for heating plating tanks (for example, install small natural gas burner system on each tank requiring heating). (hot vats in Plating Shop)	1.1
Eliminate the use of steam for heating plating tanks (for example, install small natural gas burner system on each tank requiring heating). (hot cleaning vats in Pipefitting Shop)	1.1
Install VFD on air compressor in plating shop.	1.1
Install automatic dampers to close exhaust ducts when fans are de-energized. (cleaning area in Pipefitting Shop)	1.9
Replace air agitation with electric agitators in tanks. (Plating Shop)	2.2
Install automatic dampers to close exhaust ducts when fans are de-energized. (Painting Shop)	2.5
Install common computer control system to control compressor operations.	2.6
Install circulating fans in high-bay buildings to destratify the heated air in wintertime, ventilate in summertime. (Shipfitting Shop)	2.7

Description of ECO	Payback yr*
Install circulating fans in high-bay buildings to destratify the heated air in wintertime, ventilate in summertime. (Pipefitting Shop)	2.7
Insulate exposed steam piping in Building 510.	2.8
Install condensate return system in some buildings not now connected to existing return main.	2.8
Consider power washer and vacuum drier to eliminate manual steam cleaning and subsequent long drying time for motor parts. (Motor Rewinding Shop)	5.0
Add variable frequency drive to combustion air fan supplying air to several furnaces in forge shop.	8.6

*Estimates of energy savings for application of ECOs to Norfolk Naval Ship Yard.

4 DOD-Wide Opportunities for Process Energy And Pollution Reduction

4.1 Overview

One of the objectives of this study was to identify specific PEPR opportunities at the bases that were the subject of the site visits. The opportunities found were discussed in the previous chapter, as well as some other opportunities identified in previous studies of the bases visited. The first part of this chapter reviews the opportunities that have been suggested or identified in other DOD-wide general studies, for comparison with the ECOs identified here.

Another objective of this study was to extrapolate the specific findings of the site visits with respect to PEPR opportunities to develop aggregated estimates of potential process energy savings for bases across the DOD as a whole. These aggregated estimates are developed below. First, the potential energy savings that were estimated for specific process types for specific bases were extrapolated to similar processes at other bases like those surveyed, i.e., Army depots, Air Force Air Logistics Centers (ALCs), and Naval shipyards.

Then potential energy savings were estimated for all process-oriented bases, to estimate the total PEPR opportunities that may be possible throughout all of DOD's industrial facilities. The total population of DOD industrial facilities includes, in addition to the types of bases surveyed, Army ammunition plants and arsenals, and Navy industrial facilities (Air Force process activities appear to be concentrated at ALCs according to the DEIS database). This latter total aggregation is based on the assumption that, if it were possible to survey all DOD industrial processes, an average typical value for the fraction of potential energy savings could probably be found. Thus, a typical factor for potential energy savings could be applied to processes and bases not surveyed, even though the processes carried out at such bases are probably not the same as those at the base types surveyed.

4.2 Identification of PEPR Opportunities From Energy and Pollution Prevention Studies

4.2.1 Institute for Defense Analysis Study

The IDA report (IDA, August 1994) presents lists of process-oriented ECOs that were assumed to be applicable to the four bases included in the study (three base types and one anomaly). These lists of ECOs were generated by conducting site visits and discussions with energy managers, and by examining lists of ECOs found from energy audits of industrial plants in the private sector and apparently scaling them to the size or energy usage of each DOD plant. (This approach was described in more detail in Chapter 2.) Each list of ECOs would then represent a mix of generic investment opportunities with different costs and paybacks assumed to represent a mix of ECOs that might be applicable to each type of DOD industrial facility. The results gave some indication of the amount of payback and the potential energy savings as a function of the amount of investment.

It is of interest to examine these lists of ECOs from the IDA study and compare them with the types of ECOs found from the site visits. The ECOs on IDA's lists would not, of course, be associated with a specific process, as the site visit ECOs are. Such a comparison would perhaps help support IDA's results, which might represent a more comprehensive, complete picture of the economics of potential ECOs at DOD plants, if the ECOs found from the two approaches were found to be similar. On the other hand, the IDA lists could also help point out additional ECOs that might be considered in future site visits and analyses of opportunities at DOD plants.

Tables 37, 38, and 39 list ECOs included in IDA's analyses for Puget Sound Naval Ship Yard, Holston Army Ammunition Plant, and Tinker Air Force Base (an ALC). The first thing to notice about these lists of ECOs is that they are very general, without any detail with respect to being associated with a specific process or building. The second thing to notice is that the majority of ECOs on these lists are concerned with lighting/envelope types of opportunities. A third point of interest is that most of these ECOs appear to be the kind of opportunity found on a typical energy audit, for example, generate steam more efficiently, reduce heat losses, turn equipment off (perhaps with automatic controls), return steam condensate, fix steam traps, destratify heated air, etc. These opportunities are important, of course, but overlooked in this approach is the kind of challenge to the process which might result in possible process changes and the introduction of new and more efficient technology, which is the main goal of the PEPR approach (SAIC November 1995). Process modernization is a line item for Puget Sound, but no more detail is available on what this item comprises.

Table 37. List of ECOs for Puget Sound Naval Shipyard from Institute for Defense Analysis Study.

Name	Initial Cost	Annual Savings	Type	Funding	Estimated Life
ECOS Used in Analysis					
Convert From Coal/Oil to Gas	$6,600,000.00	$1,650,000.00	Other	ECIP	10 years
Burn Coal	$8,000.00	$214,000.00	Other	Local	10 years
Temp Setpoint	$523.00	$21,515.00	Lighting/Envelope	Local	5 years
Tank Covers**	$2,368.00	$39,043.00	Process Equipment	Local	5 years
Vinyl Curtain	$3,742.00	$14,861.00	Lighting/Envelope	Local	5 years
Exhaust	$408.00	$1,565.00	Lighting/Envelope	Local	5 years
Tank Covers**	$6,124.00	$22,618.00	Process Equipment	Local	5 years
Superheat Reduction	$15,000.00	$130,000.00	Steam Generation/Distribution	Local	2 years
Night Setback**	$4,355.00	$14,889.00	Lighting/Envelope	Local	5 years
Shut Off Lights	$885.00	$1,867.00	Operating Practices	Local	5 years
Heat Exchanger**	$8,040.00	$13,064.00	Process Equipment	Local	5 years
Light control	$110.00	$175.00	Lighting/Envelope	Local	5 years
Tank Insulation	$10,677.00	$16,104.00	Process Equipment	Local	5 years
Water Heater	$325.00	$482.00	Lighting/Envelope	Local	5 years
Steam Coils	$29,939.00	$33,793.00	Process Equipment	Local	5 years
Weatherstrip**	$15,579.00	$15,261.00	Lighting/Envelope	Local	5 years
Steam Traps - FY93	$60,626.00	$117,381.00	Steam Generation/Distribution	Local	2 years
Lighting**	$4,771.00	$3,718.00	Lighting/Envelope	Local	5 years
Steam Traps - FY92	$176,135.00	$320,739.00	Steam Generation/Distribution	Local	2 years
Setback**	$21,259.00	$14,096.00	Lighting/Envelope	Local	5 years
Air Compressors	$152,124.00	$53,295.00	Compressed Air	Local	10 years

Name	Initial Cost	Annual Savings	Type	Funding	Estimated Life
Radiator Control**	$12,496.00	$7,575.00	Lighting/Envelope	Local	5 years
Setback**	$4,869.00	$2,691.00	Lighting/Envelope	Local	5 years
Radiator Control**	$20,123.00	$10,609.00	Lighting/Envelope	Local	5 years
Destratification**	$44,791.00	$23,415.00	Lighting/Envelope	Local	5 years
Weatherstrip**	$7,141.00	$3,677.00	Lighting/Envelope	Local	5 years
Heat Zoning	$5,607.00	$2,782.00	Lighting/Envelope	Local	5 years
Supply Air	$2,601.00	$1,214.00	Lighting/Envelope	Local	5 years
Temp Setback**	$7,952.00	$3,700.00	Lighting/Envelope	Local	5 years
Insulate**	$4,057.00	$1,865.00	Lighting/Envelope	Local	5 years
Destratification**	$21,259.00	$9,649.00	Lighting/Envelope	Local	5 years
Envelope - FY93**	$277,014.00	$125,463.00	Lighting/Envelope	Local	5 years
Destratification**	$11,360.00	$5,015.00	Lighting/Envelope	Local	5 years
Doors	$14,017.00	$5,703.00	Lighting/Envelope	Local	5 years
Weatherstrip**	$36,190.00	$14,560.00	Lighting/Envelope	Local	5 years
Lighting**	$8,114.00	$3,205.00	Lighting/Envelope	Local	5 years
Process Modernization	$73,274.00	$28,513.00	Process Equipment	Local	5 years
Outside Air	$14,281.00	$5,318.00	Lighting/Envelope	Local	5 years
EMCS**	$12,571.00	$4,372.00	Process Equipment	Local	5 years
ECOS Excluded Due to Low SIR					
Weatherstrip**	$15,742.00	$4,387.00	Lighting/Envelope	Local	5 years
Heat Recovery**	$11,815.00	$3,256.00	Process Equipment	Local	5 years
EMCS**	$41,868.00	$11,337.00	Process Equipment	Local	5 years

Name	Initial Cost	Annual Savings	Type	Funding	Estimated Life
Envelope - FY94**	$214,106.00	$55,578.00	Lighting/Envelope	Local	5 years
Insulate**	$5,031.00	$1,303.00	Lighting/Envelope	Local	5 years
Miscellaneous Other	$216,754.00	$55,578.00	Lighting/Envelope	Local	5 years
Weatherstrip**	$2,759.00	$688.00	Lighting/Envelope	Local	5 years
Water	$4,057.00	$992.00	Lighting/Envelope	Local	5 years
Lighting**	$1,947.00	$475.00	Lighting/Envelope	Local	5 years
Exhaust Air	$8,666.00	$1,955.00	Process Equipment	Local	5 years
Heat Exchanger**	$18,170.00	$3,754.00	Process Equipment	Local	5 years
Heat Recovery**	$102,729.00	$20,965.00	Process Equipment	Local	5 years
Replace Tank	$3,538.00	$653.00	Process Equipment	Local	5 years
Water Heaters	$5,518.00	$1,001.00	Lighting/Envelope	Local	5 years
Process Heat Recovery	$239,758.00	$43,292.00	Process Equipment	Local	5 years
Destratification**	$60,208.00	$10,558.00	Lighting/Envelope	Local	5 years
Condensate Return	$451,400.00	$74,000.00	Steam Generation/Distribution	ECIP	5 years
Lamps**	$1,947.00	$316.00	Lighting/Envelope	Local	5 years
Lighting**	$1,581.00	$242.00	Lighting/Envelope	Local	5 years
Forge Furnaces	$299,748.00	$45,126.00	Process Equipment	Local	5 years
Insulation	$4,355.00	$645.00	Lighting/Envelope	Local	5 years
Weatherstrip**	$974.00	$133.00	Lighting/Envelope	Local	5 years
Insulate**	$76,923.00	$10,443.00	Lighting/Envelope	Local	5 years
Lamps**	$1,785.00	$240.00	Lighting/Envelope	Local	5 years
Hot Water	$9,526.00	$1,274.00	Lighting/Envelope	Local	5 years

Name	Initial Cost	Annual Savings	Type	Funding	Estimated Life
Heat Recovery**	$55,161.00	$7,324.00	Process Equipment	Local	5 years
Lamps**	$974.00	$128.00	Lighting/Envelope	Local	5 years
Process Insulation	$107,728.00	$14,034.00	Process Equipment	Local	5 years
Lighting**	$41,707.00	$4,706.00	Lighting/Envelope	Local	5 years
Heat Recovery**	$136,661.00	$15,141.00	Process Equipment	Local	5 years
Light Control**	$40,247.00	$4,270.00	Lighting/Envelope	Local	5 years
Insulate**	$49,172.00	$4,641.00	Lighting/Envelope	Local	5 years
Lighting**	$42,377.00	$3,956.00	Lighting/Envelope	Local	5 years
Heat Recovery**	$59,945.00	$5,435.00	Process Equipment	Local	5 years
Proc Insulation**	$6,207.00	$481.00	Process Equipment	Local	5 years
Lighting**	$52,905.00	$3,513.00	Lighting/Envelope	Local	5 years
Lighting**	$12,697.00	$651.00	Lighting/Envelope	Local	5 years
Lighting**	$5,042.00	$252.00	Lighting/Envelope	Local	5 years
Lighting**	$34,064.00	$1,197.00	Lighting/Envelope	Local	5 years
Lighting**	$37,070.00	$892.00	Lighting/Envelope	Local	5 years
Heat Exchanger**	$114,842.00	$2,700.00	Process Equipment	Local	5 years
Burner	$22,833.00	$533.00	Process Equipment	Local	5 years
Heat Exchanger**	$98,769.00	$1,840.00	Process Equipment	Local	5 years
Heat Exchanger**	$71,879.00	$1,336.00	Process Equipment	Local	5 years
Light Control	$1,834,274.00	$33,081.00	Lighting/Envelope	ECIP	5 years
Electrical System Modifications	$52,459.00	$683.00	Lighting/Envelope	Local	5 years
Process Insulation**	$2,402.00	$12.00	Process Equipment	Local	5 years

Name	Initial Cost	Annual Savings	Type	Funding	Estimated Life
Replace Tanks	$74,847.00	$0.00	Process Equipment	Local	5 years

* Sources: Data supplied by PSNS personnel, including several previous engineering studies.; Acurex Environmental 6 October 1993.
** Because several studies used were for only a single building or a small group of buildings, several types of ECOs were repeated. This list has been screened to avoid double counting: that is, multiple entries with the same name refer to different pieces of equipment.

Table 38. List of ECOs for Holston AAP from Institute for Defense Analysis Study.

Name*	Initial Cost	Annual Savings	Type	Funding	Estimated Life
ECOS Used in Analysis					
Reduce use of compressed air to minimum; use smaller compressor	$1,594.00	$47,271.00	Compressed Air	Local	2 years
Repair and eliminate leaks in steam lines and valves	$1,837.00	$48,502.00	Steam Generation/Distribution	Local	2 years
Eliminate leaks in lines and valves carrying compressed air or other gases	$2,494.00	$46,916.00	Compressed Air	Local	2 years
Adjust (tune) burners for optimal air/fuel ratio	$5,684.00	$55,436.00	Steam Generation/Distribution	Local	2 years
Install turbulator	$31,823.00	$60,806.00	Process Equipment	Local	5 years
Install compressor air intakes in coolest locations	$5,560.00	$7,929.00	Compressed Air	Local	5 years
Install controls to operate equipment only when loaded	$76,675.00	$90,978.00	Operating Practices	Local	5 years
Install boiler insulation, or upgrade to optimal thickness	$8,524.00	$23,177.00	Steam Generation/Distribution	Local	2 years
Shut down process equipment when not in use or set back its temperature	$29,104.00	$74,671.00	Operating Practices	Local	2 years
Return steam condensate to boiler plant	$17,030.00	$41,491.00	Steam Generation/Distribution	Local	2 years
Install, upgrade, or repair insulation on steam lines	$15,835.00	$38,254.00	Steam Generation/Distribution	Local	2 years
Keep boiler tubes clean, both firesideand waterside	$19,935.00	$41,186.00	Steam Generation/Distribution	Local	2 years
Use most efficient equipment at its maximum capacity	$16,036.00	$32,447.00	Operating Practices	Local	2 years
Insulate bare tanks, vessels, lines, and process equipment	$22,210.00	$25,874.00	Process Equipment	Local	2 years

Name*	Initial Cost	Annual Savings	Type	Funding	Estimated Life
Monitor boiler efficiency and improve control capability, or add automatic controls	$186,326.00	$178,439.00	Steam Generation/Distribution	Local	2 years
Optimize plant power factors	$100,374.00	$72,493.00	Operating Practices	Local	2 years
Use waste heat from hot flue gases to preheat boiler feed water (economizer)	$84,897.00	$60,721.00	Steam Generation/Distribution	Local	2 years
ECOS Excluded Due to Low SIR	$809,000.00	$211,000.00	Process Equipment	Local	5 years
Insulate lines	$65,000.00	$14,000.00	Lighting/Envelope	Local	5 years
Insulation	$156,000.00	$31,000.00	Lighting/Envelope	Local	5 years
Relamp	$250,000.00	$21,000.00	Process Equipment	Local	5 years
Tank insulation					

* Sources: DEICO database and a list generated by Holston AAP personnel; Acurex Environmental 6 October 1993.

Table 39. List of ECOs for Tinker AFB from Institute for Defense Analysis Study.

Name*	Initial Cost	Annual Savings	Type	Funding	Estimated Life
ECOS Used In Analysis					
Improve lubrication practices for motor-driven equipment	$0.00	$1,753.00	Process Equipment	Local	5 years
Locate causes of demand charges and reschedule operations	$1,645.00	$700,322.00	Operating Practices	Local	2 years
Insulate care tanks, lines, and process equipment	$5,903.00	$60,101.00	Operating Practices	Local	2 years
Cover open tanks with floating insulation	$19,089.00	$73,250.00	Process Equipment	Local	5 years
Use most efficient equipment at maximum capacity	$16,725.00	$132,091.00	Operating Practices	Local	2 years

Name*	Initial Cost	Annual Savings	Type	Funding	Estimated Life
Reduce operating time of equipment to minimum required**	$10,556.00	$66,394.00	Operating Practices	Local	2 years
Adjust (tune) boilers for optimal air/fuel ratio	$60,191.00	$352,734.00	Steam Generation/Distribution	Local	2 years
Eliminate leaks in lines and valves carrying compressed air or other gases	$21,877.00	$124,333.00	Compressed Air	Local	2 years
Reduce operating time of equipment to minimum required[a]	$8,985.00	$48,206.00	Operating Practices	Local	2 years
Use energy efficient belts and other mechanisms	$32,194.00	$62,683.00	Process Equipment	Local	5 years
Increase amount of condensate returned	$9,734.00	$43,990.00	Steam Generation/Distribution	Local	2 years
Shut down process equipment when not in use or set back temperature	$69,989.00	$247,274.00	Operating Practices	Local	2 years
Monitor boiler efficiency and improve control capability, or add automatic controls	$39,563.00	$134,722.00	Steam Generation/Distribution	Local	2 years
Install, upgrade, or repair insulation on steam lines	$14,205	$40,686	Steam Generation/Distribution	Local	2 years
Install demand controller/load shedder	$281,369	$298,489	Operating Practices	Local	5 years
Reduce the pressure of compressed air system to the minimum required	$42,060	$81,200	Compressed Air	Local	2 years

* Source: DEICO database.
** Due to the structure of the database, this ECO appears twice: once for electrical equipment and once for natural gas-consuming equipment.

4.3 U.S. Army Concepts Analysis Agency Study

The U.S. Army Concepts Analysis Agency (CAA) conducted a Pollution Abatement and Prevention Analysis (PAPA) study (Leibel July 1994) to develop a methodology for optimizing PAPA investment decisions. The PAPA approach involves the quantification of pollution prevention opportunities (PPOs) in terms of capital costs and operating costs, and environmental and energy benefits. The focus of the study is on PPOs, not energy conservation opportunities (ECOs), although ECOs can be included if they are characterized in the same fashion as the PPOs. The PAPA Investment Model (PIM) involves selection of an objective function (e.g., maximize pollutant reduction, maximize cost savings, maximize energy savings, minimize investment/life cycle cost) or a "weighted" combination of these functions, which is then used as the basis for the optimization calculations. A budgetary constraint figure is used in the analysis. The net result is a year-by-year investment plan that identifies which PPOs (or ECOs) to implement based on the budget constraints.

For the purposes of the present study, the PAPA study was of interest in terms of the PPO data used, as well as the methodology itself. The principal interest was in those PPOs with a significant energy savings component. A total of 26 PPOs were identified for eight AMC installations to illustrate the methodology. The PIM outputs in terms of recommended schedules and aggregated impacts for the 26 PPOs are listed in Tables 40 and 41, which are taken from the report (Leibel, July 1994). This optimization is based on maximizing pollution reduction, assuming a $2.02 million annual budget constraint over a 6-year period. If only those options having a payback of less than 2 years are included in the portfolio (10 PPOs), and the same objective function is selected (maximize pollution reduction), then the results would change as shown in Table 42.

Table 40. Implementation of PPOs.

PPOs*	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99
Vehicle hull blasting unit (ANAD)		1				
Airframe paint stripping (CCAD)					1	
Laser rotor paint stripping (CCAD)						1
Paint solvent recovery system** (CCAD)	1					
Alum conv coating filtration system (CCAD)	1					
Replace chlorinated solvent degreasers (CCAD)	1					
Coolant recovery system upgrade (CCAD)	1					
Electrodialytic system (CCAD)	1					

PPOs*	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99
Upgrade industrial waste treatment plant (CCAD)				1		
Deionize spray rinse systems** (CCAD)		1				
Waterjet metal spray removal system** (CCAD)			1			
Aqueous ultrasonic cleaning system** (CCAD)			1			
Robotic waterjet paint/rust removal system (CCAD)						1
Intermediate size plastic blasting media** (CCAD)	1					
High pressure aqueous wash system (LEAD)				1		
Line trough system integration [K-5] (LSAAP)			1			
Industrial sewer replacement (LSAAP)				1		
Sump and trough canopy system [Area B] (LSAAP)	1					
Sump and trough system installation [G-7] (LSAAP)				1		
Mechanical cleaning system** (LSAAP)	1					
Treated waste water equipment installation (LSAAP)		1				
High pressure aqueous wash systems** (RRAD)		1				
Electrodialysis plating system** (TOAD)	1					
Organic washwater cleaning system** (TEAD)	1					
Electrodialysis plating solution recycling** (WA)			1			
IONSEP electropolish solution recycling** (WA)	1					

* Source: Ref. 10.

** Projects with less than 2 years simple payback

Legend:

ANAD - Anniston Army Depot
CCAD - Corpus Christi Army Depot
LEAD - Letterkenny Army Depot
LSAAP - Lone Star Army Ammunition Plant
RRAD - Red River Army Depot
TEAD - Tooele Army Depot
TOAD - Tobyhanna Army Depot
WA - Watervliet Arsenal

In a follow-up analysis (U.S. Army CAA, October 1994), the PIM was applied to a combination of PPOs and ECOs, to determine the optimum investment decision and scheduling. The data for the ECOs was based on the Renewables and Energy Efficiency Planning (REEP) (U.S. Army Corps of Engineers July 1993) program, with all appropriate ECOs being calculated for each site. Figure 4 illustrates the investment strategy in terms of the mix of PPOs and ECOs recommended. Table 43 shows the aggregated impacts for this case.

Table 41. Selected output for 26 PPOs.

Objective	Cumulative FY 94–FY 99 Impacts	Cumulative Life Cycle Impacts
Investment cost	$12.1 million	$12.1 million
Pollution reduction (kg)	3.02 million	8.11 million
Cost savings	$15.5 million	$56.8 million
Energy savings (kWh)	2.44 million	4.91 million
Source: Leibel, July 1994.		

Table 42. Selected output for 10 PPOs with less than 2-year payback.

Objective	Maximize Pollution Reduction Case (FY94–FY99)	Life Cycle Impacts
Investment Cost	$3.02 million	$3.02 million
Pollution reduction (kg)	1.31 million	3.80 million
Cost savings	$15.3 million	$35.9 million
Energy savings (kWh)	1.69 million	2.14 million
Source: Leibel, July 1994.		

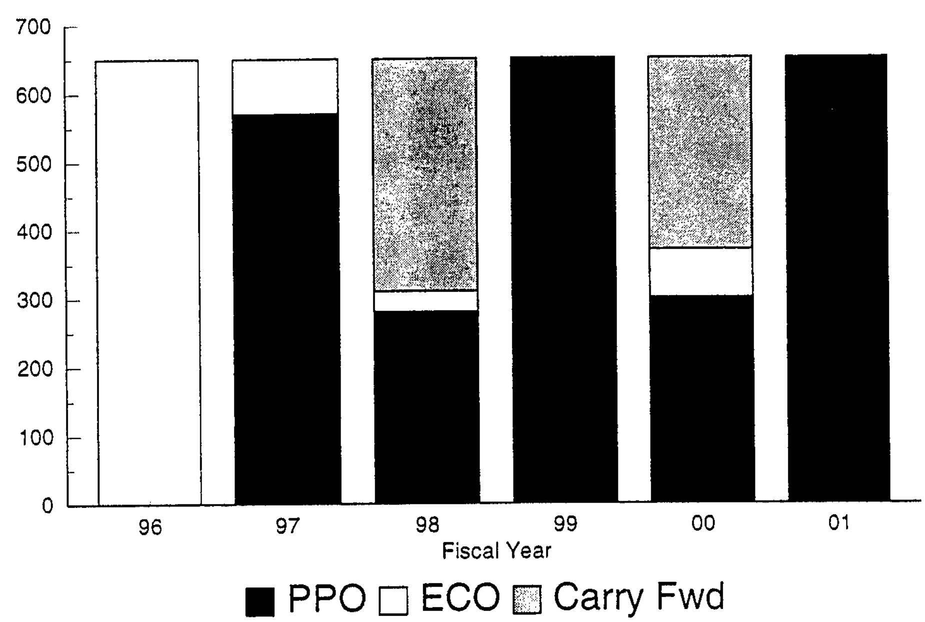


Figure 4. Selected output for combination of PPOs and ECOs.

Table 43. Selected output for combination of PPOs and ECOs.

Objective	Life Cycle Impacts
Investment Cost (FY96-01)	$3.84 million
Pollution reduction (kg)	166.4 million
Cost savings	$51.8 million
Energy savings (kWh)	2,672 million
Source: U.S. Army CAA, October 1994.	

Table 44. Selected industrial technologies in CLEAN.

Commercial Coatings • Gas paint curing for auto refinishing • IR paint curing for auto refinishing
Curing of Coatings • Electric IR (high solids, powder, solvent-based, water-based coatings) • Gas IR (high solids, powder, solvent-based, water-based coatings) • Natural gas oven (high solids, powder, solvent-based, water-based coatings)
Industrial Annealing of Steel • Indirect resistance • Induction • Natural gas furnace
Industrial Auto Body Painting • Electric IR (high solids, solvent-based, water-based coatings) • Gas IR (High solids, solvent-based, water-based coatings) • Gas oven (high solids, solvent-based, water-based coatings)
Metal Billet Heating • Direct resistance • Indirect resistance • Induction • NG-fired furnace • Oil-fired furnace
Metal Melting for Foundries (Iron & Aluminum) • Induction, resistance, plasma-type furnaces • Fossil-fired furnace • Induction, resistance, plasma-type furnaces • Fossil-fired furnace
Separation and Concentration Technologies • Freeze concentration • Thermal fossil-fired
Source: EPRI, December 1994.

As with the other approaches to aggregating energy impacts, the most important element is adequate data, data on the PPOs/ECOs, and information on their applicability to each installation.

4.3.1 CLEAN Emissions Software and Database

The Electric Power Research Institute (EPRI) has developed a Comprehensive Least Emissions Analysis (CLEAN) computer program (EPRI December 1994) to determine the impacts of various end-use technologies on energy use and the environment. More than 50 industrial technologies are included, a number of which may be applicable to DOD industrial installations. Table 44 lists some of the process-specific industrial technologies available in Version 2.0 of the program that may be applicable to DOD industrial facilities.

For electric technologies, CLEAN uses hourly electric demand profiles and marginal emissions factors to determine the impacts on utility emissions. For nonelectric technologies, representative performance values are used with standard emissions factors to make comparable estimates. Capital and operating cost data input by the user, along with financial parameters (e.g., interest rates), can be used to calculate the economics of investing in the technology. The calculations can be performed on

a comparative basis to aid in investment decisions. Version 3.0 of CLEAN will include default cost data.

The data contained in CLEAN, as well as some of the calculation routines, can be useful in evaluating the energy, environmental, and economic impacts of new/ alternative industrial technologies. However, for the present study, for the processes of interest, it was determined that there was not sufficient detail to determine whether the data could be applied directly. For this reason, it was not used in quantifying ECOs.

4.4 Analysis of DOD-Wide PEPR Opportunities

4.4.1 Opportunities at Surveyed Base Types

As the result of the collection and the analysis of the data from the site visits and other sources, an overall view of potential PEPR opportunities has emerged for those processes and bases surveyed. The results can be used to estimate aggregated energy savings across bases of the same types. This approach assumes that these other bases have much the same processes.

As the first step in the approach, energy savings factors were developed for the percent of annual use identified for savings in thermal energy and electricity, treated separately, for each of the three base types surveyed. Energy investment factors were also calculated for identified investments in terms of (investment $)/(annual MBtu saved). The calculation of these factors is shown in Table 45.

The relatively low values for the energy savings factors for Norfolk were discussed in Section 3.3.4.

An interesting observation that can be made about the investment factors is that it apparently takes a greater average investment to save 1 MBtu of electricity annually compared to the average investment required to save 1 MBtu of thermal energy annually. One reason for this is that there are significant low-/no-cost opportunities to save thermal energy where there is a great deal of waste and inefficiency, compared to much less waste of electricity, which of course is a more expensive form of energy. The high investment factor for thermal energy for Norfolk is a reflection of the mix of ECOs, which perhaps has fewer identified low-/no-cost opportunities to save on wasted energy, as well as the higher value placed on thermal energy at Norfolk, which makes more costly investments appear worthwhile.

Table 45. Energy savings and investment factors for surveyed bases.

	Annual Use (MBtu)	Identified Savings		Identified Investments	
		MBtu/yr	% Annual Use	$	$/Annual MBtu Saved
Thermal Energy					
Anniston AD	331,118	75,546	22.8	394,200	5.22
Robins AFB	976,148	138,737	14.2	529,665	3.82
Norfolk NSY	651,532	56,424	8.7	644,957	11.43
Electricity					
Anniston AD	210,500	17,595	8.4	357,705	20.33
Robins AFB	927,401	19,547	2.1	651,928	33.35
Norfolk NSY	558,011	20,489	3.7	338,575	16.52
Total Energy					
Anniston AD	541,618	93,141	17.2	751,925	8.07
Robins AFB	1,903,549	158,284	8.3	1,181,593	7.47
Norfolk NSY	1,209,543	76,913	6.4	983,532	12.79
Totals	**3,654,710**	**328,338**	**9.0**	**2,917,050**	**8.88**

To estimate and aggregate the potential energy savings at bases similar to those surveyed requires data on the energy consumption of each of the candidate bases, broken down as thermal energy and as electricity. This information is available (as shown in Chapter 2). The candidate bases to be included in the aggregation need to be selected as well. For the Air Force, the bases in question are the five ALCs, and the Navy, the eight shipyards. However, in the Army, process activities are carried out at a number of different types of bases. The Army base surveyed was a maintenance depot, but there are ammunition plants, arsenals, supply depots, proving grounds, depot activities, engine and tank plants, a missile range, and other miscellaneous types in the AMC. The Army bases selected for this aggregation and assumed to be like Anniston, with the same sorts of process activities, are shown in Table 46.

The application of the energy savings and investment factors to the energy consumption data at bases assumed to be similar to those surveyed is shown in Table 47. The table shows the estimated energy savings for each energy type, as well as the total expected savings, for each type of base. The total expected energy savings at all of the bases included in this analysis is 2,107,000 MBtu/yr, comprised of savings of 1,787,000 MBtu/yr in thermal energy and 320,000 MBtu/yr in electricity. These savings could be achieved with investments of about $11.2 million in thermal energy ECOs and $7.4 million in ECOs pertaining to electricity.

Table 46. AMC bases selected for aggregation of energy savings.

Base Name	Thermal Energy Mbtu/yr	Electricity Mbtu/yr	Total Energy Mbtu/yr	Percent Thermal Energy	Selected *	**
Aberdeen PG	1004602	800434	1805036	55.66		
Anniston DPT	330285	211183	541468	61.00	X	X
Badger AAP	21961	12533	34494	63.67		
Corpus Christi DPT	4649	186084	190733	2.44	X	X
Detroit Ars Tank PL	435609	0	435609	100.00		X
Detroit Arsenal	241575	139363	380938	63.42		X
Dugway PG	119508	107366	226874	52.68		
Fort Monmouth	659554	300184	959738	68.72		
Hawthorne AAP	188914	28099	217013	87.05		X
Holston AAP	2149688	213459	2363147	90.97		X
Indiana AAP	75706	47741	123447	61.33		
Iowa AAP	544874	66745	611619	89.09		X
Jefferson PG	48059	14478	62537	76.85		
Kansas AAP	174910	40096	215006	81.35		X
Lake City AAP	466596	143285	609881	76.51		X
Letterkenny Army DPT	391858	186766	578624	67.72	X	X
Lexington Blue Grass	166150	59850	226000	73.52	X	X
Lima Tank Plant	232795	175039	407834	57.08		X
Lone Star AAP	574452	53362	627814	91.50		X
Longhorn AAP	424641	73089	497730	85.32		X
Louisianna AAP	156160	120400	276560	56.47		X
McAlester AAP	186770	45502	232272	80.41		X
Milan AAP	104580	43174	147754	70.78		
Mississippi AAP	46870	30540	77410	60.55		
Natick Dev Cen	93785	42567	136352	68.78		
Newport AAP	287340	14761	302101	95.11		X
Picatinny ARS	847022	204282	1051304	80.57		
Pine Bluff ARS	442994	86045	529039	83.74		X
Pueblo DPT	89834	28714	118548	75.78		
Radford AAP	2326897	328354	2655251	87.63		X

Base Name	Thermal Energy Mbtu/yr	Electricity Mbtu/yr	Total Energy Mbtu/yr	Percent Thermal Energy	Selected *	**
Ravenna AAP	14354	6478	20832	68.90		
Red River DPT	381971	201306	583277	65.49	X	X
Redstone ARS	314015	1386354	1700369	18.47		X
Rock I. ARS	779574	373840	1153414	67.59		X
Sacramento Army DPT	136754	62513	199267	68.63	X	X
Savanna Depot Activi	103511	16447	119958	86.29		
Scranton AAP	106186	95916	202102	52.54		X
Seneca Army Depot	65340	27048	92388	70.72		
Sierra Army Depot	79626	46048	125674	63.36		
Sunflower AAP	394819	46772	441591	89.41		X
Tobyhanna AD	569680	138254	707934	80.47	X	X
Tooele Dpt	376116	241432	617548	60.90	X	X
Twin Cities AAP	207158	122124	329282	62.91		X
Umatilla Army DPT	29339	10481	39820	73.68		
Vint Hill Farms Stat	87229	67581	154810	56.35		
Volunteer AAP	0	14823	14823	0.00		
Watervliet ARS	335550	157418	492968	68.07		X
White Sands M.R.	483805	384113	867918	55.74		
Yuma PG	10172	123086	133258	7.63		

* Assumed to be similar to surveyed base (maintenance depot).

** AMC process-oriented base.

It should be emphasized that these estimated potential PEPR energy savings are by no means all-inclusive. Many processes have not been surveyed in detail. Even for those processes that have been analyzed, the analysis was not necessarily exhaustive, and additional PEPR opportunities can probably be identified. In addition, due to the nature of the PEPR methodology, some opportunities for process improvement may require additional research to prove them out, or to develop the necessary quantified estimates of energy savings and costs. *These opportunities have not been included in this estimation of aggregated energy savings.*

Table 47. Energy savings and investments for types of surveyed bases.

	Annual Use (MBtu)	Identified Savings		Identified Investments	
		% Annual Use	MBtu/yr	$/Annual MBtu Saved	$M
Thermal Energy					
AMC bases* (8)	2,357,463	22.8	537,502	5.22	2.81
ALC bases (5)	5,549,403	14.2	775,235	3.82	2.96
Naval shipyards (8)	5,446,352	8.7	473,832	11.43	5.42
Electricity					
AMC bases* (8)	1,287,388	8.4	108,141	20.33	2.20
ALC bases (5)	4,676,216	2.1	98,200	33.35	3.27
Naval shipyards (8)	3,075,442	3.7	113,791	16.52	1.88
Total Energy					
AMC bases* (8)	3,644,851	18	645,643	7.76	5.01
ALC bases (5)	10,135,619	9	873,435	7.13	6.23
Naval shipyards (8)	8,521,794	7	587,623	12.42	7.30
Totals	**22,302,264**	**9**	**2,106,701**	**8.80**	**18.54**

*Maintenance depots–see Table 46.

It is worth noting the difficulties involved in evaluating specific ECOs for estimated energy savings or costs. Consumption data generally do not exist in a form that readily allows analysis or comparisons. In addition, many process type of ECOs require having very specific data on the process operation being analyzed—data that do not exist without extensive on-site effort—to be evaluated with credible results.

4.4.2 Opportunities at All DOD Process-Oriented Bases

It is noted elsewhere in this report (see Chapter 2) that energy usage in DOD facilities has not been well characterized in previous studies with respect to process energy consumption. More studies are needed of specific processes at specific installations to understand the wide variety of DOD industrial processes and to develop a database of process energy use related to the production of DOD products. A database of this type, as a baseline, is needed to properly assess and characterize the wide variety of potential energy-saving measures that may be possible to implement with respect to DOD industrial processes, and to quantify the potential savings.

This study is therefore only an initial attempt to define and characterize specific DOD industrial processes, and to develop a database of energy usage and energy

conservation opportunities from the ground up, so to speak. The processes and the installations surveyed on the site visits represent only a small fraction of the process activities conducted at DOD facilities. However, it is believed that the types of installations surveyed are typical of DOD facilities where industrial processes are conducted, and the processes examined in detail are common to many DOD installations. It is therefore believed possible to arrive at an initial estimate of the aggregate of PEPR opportunities in DOD industrial processes by assuming average percentage savings across the board for process energy usage.

This approach has been used before, i.e., the IDA report (August 1994), but the difference in this study is that the estimated percent savings in energy have been developed by surveying specific DOD processes and associating energy savings with specific ECOs for such processes, rather than simply assuming that potential ECOs should be similar to those found by surveying industrial processes in general (i.e., those found in the DEICO database). Another difference in this study is that an attempt has been made to identify energy conservation opportunities in processes via the PEPR methodology rather than only through a more traditional type of energy audit. However, many of the PEPR opportunities found have not been evaluated quantitatively, and require more information than it was possible to collect in this project.

Thus, the approach described above to estimate aggregated energy savings and investments for bases similar to those surveyed can be extended to estimate opportunities at all DOD process-oriented bases. According to the DEIS database, DOD process-oriented bases include Army ammunition plants, the five ALCs and Arnold Engineering Development Center (AEDC) for the Air Force, and Navy shipyards and other Navy industrial facilities. The DEIS database does not include Army depots, arsenals, and other plants in this group. Since these additional DOD bases are different types from those surveyed, the processes at these bases may be quite different from those surveyed, with different PEPR opportunities. Thus, the estimated energy savings and investments for this group of bases undoubtedly have a greater range of uncertainty.

The bases included in this grand aggregation include those designated in DEIS as process-oriented bases plus additional types of Army bases, as shown in Table 46. Table 48 shows the application of the energy savings and investment factors to these groups of bases in the three services. The total expected energy savings at all bases included in this analysis is 5,664,000 MBtu/yr. The investments required to produce this total reduction in process energy consumption total approximately $48 million.

Table 48. Energy savings and investments for all DOD process-oriented bases.

	Annual Use MBtu	Identified Savings		Identified Investments	
		% Annual Use	MBtu/yr	$/Annual MBtu	$M
Thermal Energy					
AMC bases[1] (29)	13,328,980	22.8	3,039,007	5.22	15.86
AEDC + ALCs (5)	6,163,819	14.2	875,262	3.82	3.34
Naval bases[2]	10,892,704	8.7	947,664	11.43	10.84
Electricity					
AMC bases[1] (29)	4,997,411	8.4	419,783	20.33	8.53
AEDC + ALCs (5)	7,384,623	2.1	155,077	33.35	5.17
Naval bases[2]	6,150,884	3.7	227,582	16.52	3.76
Total Energy					
AMC bases[1] (29)	18,326,391	19	3,458,790	7.05	24.39
AEDC + ALCs (5)	13,548,442	8	1,030,339	8.26	8.51
Naval bases[2]	17,043,588	7	1,175,246	12.42	14.60
Totals	**48,918,421**	**12**	**5,664,375**	**8.39**	**47.50**

1 See list of AMC bases in Table 46.
2 Naval shipyards (8) plus "other Navy facilities," primarily "reserve industrial plants," which are assumed to account for an amount of energy equal to the total for the shipyards (see Section 2.3.3.1).

Although the total energy savings indicated in Table 48 appear to be a smaller proportion of the total energy consumption than is the stated goal of 20 or 30 percent reduction, it should be emphasized that the savings which have been found in the present analysis are limited to *process* savings, and many potential process changes to effect energy savings have not been quantified and included in this figure. These savings should be considered as an addition to the savings identified by the IDA study (IDA, August 1994), which was more concerned with *process facility* energy savings.

It is to be hoped that this application of PEPR methodology to the evaluation of DOD process energy consumption and potential energy savings will result in a somewhat firmer estimate of the potential savings in process energy than has been obtained previously. However, it is evident that much more work needs to be done to develop a baseline database of process characterizations and energy usage, and to identify and evaluate specific PEPR opportunities, particularly by conducting site visits to DOD bases.

5 Conclusions and Recommendations

5.1 Conclusions

1. A wide-range of energy conservation opportunities (ECOs) are available that have broad applicability to DOD industrial operations. A conservative estimate of the potential of these ECOs to save energy is on the order of 5,660,000 MBtu annually, representing 12 percent of DOD industrial energy use. This result assumes an investment of approximately $47.5 million in the most cost-effective, relatively straightforward measures. Note that this figure does not include major process re-engineering reductions, which were not quantified, or nonprocess specific options (e.g., steam system upgrade, building envelope improvements, and energy-efficient lighting, heating, ventilation, or air conditioning system options). If these other kinds of ECOs were considered, there should be ample opportunity to meet the year 2005 industrial energy use reduction goals in a cost-effective manner.

2. Many of the ECOs identified were low-cost and had very good economics (e.g., payback periods of 5 years or less). These ECOs included simple actions such as proper maintenance, schedule changes, improving equipment insulation levels, etc. Opportunities to save thermal energy were greater than those for electric energy, due to the nature of the processes evaluated. However, ECOs addressing electric energy tended to have greater cost savings potential, due to the generally higher unit price of electricity.

3. The environmental impacts of the ECOs varied from process-to-process, with those processes having significant thermal energy requirements/material transformations typically having the greatest opportunity for emissions/waste stream reductions.

4. Limited data from the installations on the types of processes and the level of process activity (e.g., production rates) make it difficult to project energy savings/environmental benefits across DOD facilities. Based on the three representative facilities (Anniston Army Depot, Robins Air Logistics Center, and Norfolk Naval Ship Yard), there are sufficient differences in processes to

warrant a greater data collection effort. Such an effort would better identify the magnitude of the opportunity.

5. Those ECOs that appear to be most widely applicable include those for electroplating, heat treating, spray painting, and cleaning or depainting. The specific ECOs will vary based on the differences in the operations. Generalizing the ECOs will work for certain processes, e.g., spray painting, but less well for others, such as heat treating.

6. The greatest opportunities for industrial energy/pollution reduction appear, as would be expected, at installations that are process-intensive (e.g., certain AMC facilities). These expend a much higher fraction of their energy for process-specific uses. In contrast, Naval shipyards such as NNSY appear to have a much smaller fraction of energy use in industrial processes. However, given the size of the shipyards, and the total energy requirements, there are still substantial opportunities.

5.2 Recommendations

1. Conduct additional selected-site visits to DOD installations to obtain information on process energy use and environmental data. These visits should include installations that are representative of other major functions not already covered in the site visits conducted under this study (e.g., other types of AMC installations). It may also be beneficial to include one more of the same type of installation as has been visited under this study, bringing the total number to perhaps 10.

2. Survey DOD installations to obtain a quantitative assessment of the number and the types of processes, and level of process activities. The results of such a survey would be useful in establishing a baseline for projecting opportunities on a DOD-wide basis. Such a survey could be done by mail or electronic means.

3. Quantify ECOs that have been identified, but not already quantified due to a lack of sufficient information about the process or the new/alternative technology. The scope of this effort would include a number of re-engineering suggestions.

4. Coordinate data collection/opportunity assessment efforts with other related efforts such as those being undertaken by pollution prevention/pollution abate-

ment programs. A review of some of the studies indicates sufficient commonality of interest that this coordination would strengthen such efforts.

5. Follow-through with Anniston, Robins, and Norfolk in assisting them to plan/implement the recommended ECOs. If possible, work to ensure that a way to evaluate the impacts of the ECOs is incorporated as part of project implementation. This would be particularly valuable for those ECOs for which there is little on-base experience.

References

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